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THE FEEDING VALUE OF CANADIAN WESTERN BARLEY FOR BACON HOGS[1]

E. W. CRAMPTON[2], G. W. MUIR[3], AND R. G. KNOX[4]

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The feeding value of barley for pigs relative to other cereals, is a matter on which authors are not entirely agreed. Kellner (6) states, "The principal use . . . is in the feeding of pigs; the pork and bacon from barley-fed swine are of unexcelled quality. Where pigs are under three months old, oats are, however, preferable. . . . the amount of chaff . . . determines in the first place the feeding value." Bull and Carroll (1) write, "for growing pigs it [barley] is fully as good as corn. . . . For fattening hogs, barley is about 5–10% less valuable than corn. It produces a higher quality of pork, however. It produces a firmer flesh containing more lean and less fat than the flesh produced by corn." Morrison (8), though pointing out the excellent carcass quality produced by barley rations finds from averaging some 17 feeding trials that pigs fed corn rations require nearly 60 pounds less feed (grain plus supplement) per 100 pounds of live weight gain, and average 0.11 pounds less weight gain per day. From other trials he found that, "With feeds at representative prices, ground barley was worth about 91 per cent as much as corn in these tests."

The above statements are from well known texts on feeds and feeding and, though based on experimental evidence, are of necessity somewhat general and represent the particular author's interpretation of the evidence available. In 1933 Crampton (2) made a critical survey of the published literature on the comparative values of the cereal grains, from which the following statements bear on the present study: "On the pound for pound basis there is not a significant difference between corn and barley for very young pigs. For growing pigs, corn rations show an advantage over the barley rations in daily gains, daily feed consumption and gain per 100 pounds feed. The finishing hogs in all but four out of seventeen comparisons made more efficient use of the corn ration, showing a net difference of about 5% in favour of that ration. Usually there also appears to be a more rapid gain made on corn, but little difference in feed consumed. If all the data for hogs are put together a weighted average based on 70 comparisons and involving some 450 pigs per group shows that . . . between corn and barley, pound for pound the following could be expected: about 7.5% faster daily gains, 1.5 to 2.0% more daily feed consumption, and 5% greater gain per 100 pounds feed eaten with corn rations." No carcass data were included in this report.

[1] The results of a co-operative project conducted with the assistance of a number of organizations. Details of the arrangement may be found on page 378.

[2] Associate Professor of Animal Nutrition, Macdonald College (McGill University), P.Q.
[3] Dominion Animal Husbandman, Experimental Farms Service, Dominion Department of Agriculture, Ottawa, Ont.
[4] Professor of Animal Husbandry, Ontario Agricultural College, Guelph, Ont.

Since the above report was issued, Hughes (5) has prepared a summary of feeding results intended to show the value of barley as a grain concentrate in pork production. He states, "Though shelled corn surpasses barley, either ground or rolled, in the production of pounds of pork, it does not surpass it in the quality of pork produced. . . . As compared with those grown and fattened on corn they [barley produced bacon cuts] are thought to be firmer both in the refrigerator room and after being processed; furthermore, the percentage of muscle and fat is well balanced."

The conclusion which is most obvious from the above resume is that barley-produced bacon is preferable to that from corn-fed pigs. Evidently the results of barley feeding otherwise have been variable, with most cases showing faster gains with corn as well as greater gains per unit of feed eaten.

It may be pointed out, however, that few if any of the reported studies have included adequate descriptions of the barley used or taken into account the variations which exist from one sample of barley to another. Some idea of the variation in chemical composition of Canadian barley samples may be had from figures published by Geddes (3).

Percentage Protein of Canadian Western Barley All Grades.

No. samples	2141
Average percentage protein	11.9%
Standard Deviation	±.95%
Range in percentage protein—minimum	8.8%
Range in percentage protein—maximum	15.4%

Winton (9) reports for United States barley the following percentage composition on a moisture free basis:

	Protein	Fat	N-free extract	Fibre	Ash
	%	%	%	%	%
Minimum	8.31	0.37	70.48	3.94	2.33
Maximum	19.94	2.51	82.13	8.99	3.63
Average	13.39	1.87	76.05	5.64	3.04

Hughes (5) points out that barley as a hog feed is deficient in vitamin A and some fractions of the B complex, which deficiencies must be made good for satisfactory results in feeding. Whether sample differences in these respects are important would seem doubtful.

In addition to gross chemical differences, barley samples may differ widely in physical characteristics, of which weight per 1000 kernels may be of significance in determining feeding value in that it is, within varieties, an index of the plumpness of the grain. Samples having low weight per 1000 kernels carry a high percentage of hull and probably are therefore of lower feeding value. For Canadian Western barley Geddes and Lehberg (4) publish the following data:

Grade of barley*	Weight per bushel	Weight per 1000 kernels
	lb.	gm.
3 C.W.	46	32.5
4 C.W.	44	29.8
5 C.W.	42	26.8
6 C.W.	38	23.1

*Grades in force prior to the revision of 1939.

The most recent evidence as to the effect of quality of barley on its feeding value is contained in the report by Wright (10) of studies at the South Dakota Agricultural Experiment Station in which market pigs were fed barley of different weights per bushel. Three feeding trials were reported, and using the lot averages as single observations the relationships between the weight per bushel of the barley fed and (1) average daily gains of the pigs and (2) pounds of feed required to produce 100 pounds of gain on the pigs may be expressed by regressions as follows:

Increase in daily gain of pigs with 1 pound increase in weight per bushel of barley fed = 0.0518 pound[1]

Increase in feed required per 100 pounds gain with each pound decrease in weight per bushel of barley fed = 18.1 pounds[1]

Of the trials reported the third, for undetermined reasons, failed to show as marked effects of light weight barley as did the first two. The regressions are therefore smaller than might have been expected from a casual perusal of the published report. The tendency to slower gains of the pigs and to lower ration efficiency resulting from the use of light weight barley is nevertheless distinctly evident. For example, the use of barley weighing 40 pounds per bushel might with equal daily feed intake be expected to decrease rate of gain of pigs about one-quarter pound per day as compared to that to be obtained on 45-pound barley, and also to raise the amount of feed necessary for each 100 pounds of gain by some 90 pounds. One-quarter pound of gain per day on an average feeding period of 120 days means a month longer to get pigs to market, and on an average of 170 pounds of gain per pig the penalty of 5 pounds lower weight per bushel means something like 150 pounds more feed needed per pig.

In the use of Canadian Western barley a further factor is involved in that what is spoken of as barley may contain appreciable quantities of non-barley, principally wild oats. Under the Canada Grain Act in force at the time (March 1937) the hereinafter reported tests were undertaken, the feed grades of Canadian Western barley were permitted tolerances of non-barley as follows:

Grade of barley	Seeds	Wild oats	Other grains	Total not to exceed
	%	%	%	%
No. 3 C.W.	1½	6	6	6
No. 4 C.W.	3	10	10	10
No. 5 C.W.	3	18	18	18
No. 6 C.W.	3	25	25	25

Thus in Canada what is legally barley meal may actually be a mixture of but 75% barley with 25% wild oats. Herein lies a fruitful source of variation in the feeding value of "barley" (unless one wishes to assume that such additions of wild oats do not alter the nutritive worth of the mixture over that of pure barley).

[1] Regressions calculated by Crampton.

It should be pointed out that the National Barley Committee was at the time of the inception of this project also preparing a revision of the statutory grades of barley which was incorporated in the general revision of the Canada Grain Act passed in 1939. In this revision the feed grades of Canadian Western barley are permitted tolerances of non-barley as follows:

Grade of barley	Wt. per bushel	Seeds	Wild oats	Other grains	Total not to exceed
	lb.	%	%	%	%
No. 1 feed	46	2	4	4	4
No. 2 feed	43	3	10	10	10
No. 3 feed	—	3	20	20	20

Another point which is of importance to the Canadian hog feeder is the fact that practically all of the data relative to the feeding value of barley have been based on tests in which fat type rather than bacon type pigs were involved. Thus not only may the rates of gain and the feed utilization reported prove inapplicable to Canadian practice, but the standards of carcass excellence used for Canadian bacon are not those by which American pork is judged.

It was in view of this uncertain position regarding the feeding value of Canadian Western barley that the National Barley Committee through a special sub-committee undertook to obtain more accurate information on this question. The study took the form of a co-operative hog feeding project supported by the Western Canadian Wheat Pools, the Dominion Department of Agriculture, and two agricultural colleges—Ontario Agricultural College, and Macdonald College (McGill University).

In so far as the actual feeding was concerned, five replicate tests were arranged and located at: (1) Dominion Experimental Farm, Nappan, Nova Scotia; (2) Dominion Experimental Station, Ste. Anne de la Pocatiere, Quebec; (3) Ontario Agricultural College, Guelph, Ontario; and (4) Macdonald College, Ste. Anne de Bellevue, Quebec. One test was undertaken at each station excepting at Macdonald College where two tests were carried. With the facilities available it was impossible to undertake all the comparisons in one year. Accordingly the project was continued over two years as indicated in the following outline.

All tests were conducted from the same plan of procedure, the following details of which are abstracted from the outline:

Animals: Bacon type pigs, preferably of Yorkshire breeding, put on test rations at an average age of 70 days and weighing at that age not less than 35 pounds each.

Allotment: All feeding lots to consist of 5 pigs, allotted with due consideration to age, weight, sex, condition and breeding.

Feeding Periods: In general, the feeding periods will correspond to those followed at the Advanced Registry Pig Testing Stations. This procedure calls for pigs to be fed a growing ration up to a weight of 100 to 110 pounds (average of lot), after which they are changed to a finishing ration. Each pig will be shipped for slaughter on reaching a weight of 200 pounds.

Feed Mixtures: Table I gives the composition of the feed mixtures fed.

TABLE 1.—COMPOSITION OF MIXTURES FED*

Year of test	Feeding lot	Barley		Wild oats	No. 3 C.W. oats	Weed seeds	Yellow corn	Protein-mineral supplement	Total mixture
		No. 3 C.W.	6-row malting						
		lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
	I	85.0						15.0	100
	II				85.0			15.0	100
1937	III						85.0	15.0	100
	IV	42.5			42.5			15.0	100
	V				42.5		42.5	15.0	100
	VI**		81.6	2.55		.85		15.0	100
	VII**		76.5	6.8		1.7		15.0	100
1938	VIII**		68.0	14.5		2.5		15.0	100
	IX						85.0	15.0	100
	X**		40.8	1.3	42.5	.4		15.0	100

The protein-mineral supplement to consist of:

Tankage (60% protein)	50 lb.
Fish Meal (non-oily)	15 lb.
Linseed oilmeal	20 lb.
Feeding bone meal	5 lb.
Ground limestone	5 lb.
Salt (iodized 0.01%)	5 lb.
Total	100 lb.

* The above mixtures are those used until pigs weighed 100–110 lbs. From then to market weight the mixtures were changed by reducing from 15% the proportion of protein-mineral supplement to 10%, and increasing the other ingredients correspondingly.

** The proportions of barley, weed seeds and wild oats are those which correspond to the probable proportion to be found in actual samples graded under the revised feed barley grades (see page 367).

The proportions used in these lots were:

Feeding Group	Pure barley	Wild oats	Weed seeds	Corresponding to grade
	%	%	%	
Lots VI and X	96	3	1	No. 1 C.W. feed barley
Lot VII	90	7	3	No. 2 C.W. feed barley
Lot VIII	80	17	3	No. 3 C.W. feed barley

Mixtures for all tests are to be prepared by one concern (Cooperative Federee de Quebec, Montreal), properly labelled and distributed to the feeding stations.

Feeding Practice: Until pigs reach 100-110 pounds, they are to be fed 3 times daily, and twice thereafter. All pigs to be hand fed to the limit of their appetites. The dry meal allowance at each feeding is to be measured for each group and the water allowance to be added at the time of feeding. During the first period (to 100–110 pounds) all pigs are to receive 15 cc. of "Noppco XX" cod liver oil daily. This oil carries a guaranteed potency of 3,000 I.U. vitamin A and 400 I.U. of D. Pigs are to be penned and confined indoors throughout the test.

Records: Standard record forms will be provided for all data relative to weights and gains of the pigs, their feed consumption and length of feeding periods. These data are to be recorded individually for each pig excepting that feed records from tests other than at Macdonald College will be for the feeding groups. Individual feed records will be taken in the Macdonald College tests.

On completion of the feeding periods each pig will be slaughtered under the provisions of the Swine Advanced Registry Programme, and the carcass data required by that programme be recorded for individual pigs by official hog graders of the Department of Agriculture.

On receipt of the feed for each test, suitable samples of each mixture are to be returned to Macdonald College for chemical analysis.

RATIONS FED

In connection with the rations used in these tests attention is called especially to those fed in the 1938 season. By the addition to barley of malting grade of the quantities of weed seeds and wild oats shown in Table I, mixtures were obtained which, other than for possible differences in the quality of the barley itself, were typical of the commercial grades of feed barley. It was believed that comparisons of these "synthetic" samples would give a clearer picture of the effect on the feeding value of excellent quality barley of varying dilutions of wild oats than could be had with actual samples of the feed grades on the market. Interpretation of the results must therefore be done with the fact in mind that actual samples

of No. 3 Canadian Western barley (new grade) for example may, because of a lighter weight of barley involved, be of lower feeding value than that shown by the "synthetic" sample of No. 3 Canadian Western barley fed to lot VIII.

The corn which was used in these rations was South African grown. There appear to be no data from which any difference in its feeding value from corn of other origin might be estimated. In so far as the value of these tests to Eastern Canadian feeders is concerned, it may be pointed out that the corn used was typical of that with which barley competes.

STATISTICAL ANALYSIS OF THE DATA

Feed Consumption

In the tests located at Macdonald College, the pigs were penned and fed individually and feed consumption for each animal recorded. For the 50 pigs involved in each of the two years, the regressions of gain on feed (b_1) and feed on gain (b_2) were calculated from the variances remaining after removal of the fraction due to kind of ration. Assuming the regressions obtained from the data of the 50 pigs to apply to pigs in all tests, it was possible from the observed individual daily live weight gains at all stations to calculate the daily feed intake of the 125 pigs fed in any one year as follows:

$$y = \bar{y} - b_1(\bar{x} - x)$$

where y is the calculated individual feed intake; $\bar{y}$, the observed average daily intake of the 125 pigs fed that year; $\bar{x}$, the observed average daily gain of the 125 pigs; x, the observed individual pig gain whose feed intake is to be calculated; and b_1, the pounds change from the mean feed consumption for each pound change in individual pig's gain from mean gain of all pigs. From these calculations a table of individual daily feed intake was prepared and subjected to the analysis of variance described below.

Live Weight Gains Corrected for Feed Intake

The chief purpose in obtaining a record of individual feed consumption was to make possible an estimate of the gains, free from the effects of varying feed intake. Differences in average gains of pigs on comparative rations may be in part due to differences in the quantities eaten, an effect which it is desirable to eliminate in order to study any possible effect of kind of feed. This has often been done by calculating a simple ratio of average gains to average feed eaten, expressing the result as gain made per unit of feed eaten.

A more accurate "corrected gain" may be calculated when individual feed and gain data are available, using the relationships—

$$x_2 = \bar{x} - b_2(\bar{y} - y)$$

when $\bar{x}$ and $\bar{y}$ are the general mean daily gain and daily feed respectively; y, the individual or sub-group daily feed intake; b_2, the pounds change from the general mean gain for each pound deviation of the individual pig's feed from the general mean feed of all pigs. The values of x_2 are the daily gains expected had the feed intake of all pigs been equal to the average daily consumption of the whole test. Such gains are freed, as well as can be done with linear regression, of the effects of varying feed intake, and differences remaining between the lot averages may therefore be credited to the effects of kind of ration uncomplicated by level of intake.

This procedure, using the regression (b_2) obtained from the individually fed hogs at Macdonald College, was used to obtain the average "adjusted" gains of the lots shown in Table IV and in Appendix Table X. In order to obtain a standard deviation applicable to these adjusted mean gains, use was made of the fact that the squared correlation between observed gain and feed is a measure of the fraction of the variance in the gains within lots associated with variations in feed intake. Hence the sum of squared deviations for gains adjusted for variations in feed intake was estimated as $(1 - r^2)S(x - \bar{x})^2$, when x is the individual gain and r the coefficient of correlation between gain and feed consumption. The standard deviation (within lots) of one individual is then obtained from this adjusted "sum of squares" in the usual way. Thus $\sigma = \sqrt{\frac{(1 - 0.366)(4.29)}{197}} = \pm 0.1175$ lb.

In obtaining the necessary difference between means of lots of 25 (*i.e.*, means of different ration groups) Wishart's[1] procedure was followed, in which the variance in the adjusted gains within lots and that ascribable to the error of the regression coefficient are both considered. In terms of the factors of this trial the standard error of a difference between two lot means becomes: $\pm\sqrt{\sigma^2\left(\frac{2}{n} + \frac{d^2}{A}\right)}$, where σ is the standard deviation of the adjusted gains, n the number of observations in the lots involved, d the maximum difference between any two of the lot means compared, and A the sum of squared deviations from which the regression (b) was calculated. The necessary difference is then obtained as usual by multiplying the determined standard error by "t".

Thus the standard error of a difference between two lot means in gain $= \pm\sqrt{(0.1175)^2\left(\frac{2}{25} + \frac{(0.79)^2}{16.85}\right)} = 0.04$; and the necessary difference becomes $(0.04 \times 1.96) = \pm 0.08$ lb.

Analysis of Variance

Individual records for each pig, and the design of the tests made possible for each item recorded an analysis of the variance, according to the scheme illustrated in Table II for the case of daily gain in weight.

TABLE 2.—ANALYSIS OF VARIANCE OF DAILY GAIN (TO MARKET)

Description	D/F	$S(x - \bar{x})^2$	σ^2	σ	F values		C.V. %
					Observed	Necessary	
Total	249	8.80					
Between sub-classes	49	4.51					
Between lots	9	2.28	.25		11.69	1.92	
Between stations	4	1.38	.34		15.92	2.41	
Interaction	36	.86	.02		1.10	1.45	
Calculated values	2						
Error	198	4.29	.02	.15			10.22

Necessary difference between lot means $= \frac{0.15}{\sqrt{25}} \times \sqrt{2} \times 1.96 = 0.08$.

Necessary difference between station means $= \frac{0.15}{\sqrt{50}} \times \sqrt{2} \times 1.96 = 0.06$.

[1] Wishart, J. Tests of significance in Analysis of Covariance. J. Royal Statistical Soc., Supplement, V. 3, No. 1, p. 79, 1936.

From this analysis certain facts concerning daily gains in these tests emerge. From the F value it is noted that there are significant differences in gains not only between the rations but also between the tests themselves at different stations. Such differences are indicated by the fact that the variance for "lots" and for "stations" is more than 1.92 and 2.41 respectively times the variance caused by the unmeasured factors affecting variability of gains (*i.e.*, error variance). Similarly there is no indication that the kind of pigs at any one station altered the relative feeding values of the rations (*i.e.*, there was no significant interaction between station and ration).

The variability in daily gains between individual pigs from unmeasured causes amounts to 0.15 pound or 10.22% of the average gains, and hence in 19 out of 20 cases differences between the average daily gains of any two ration groups greater than 0.08 pound may be taken as the result of real differences in the feeding value of the rations (*i.e.* the difference necessary between lot means to cover experimental error = 0.08 pound).

RESULTS

Table 3 gives the means and standard deviations for the items recorded during these trials. The F ratio is in all cases the variance (σ^2) for lots or for station divided by the residual variance remaining after removal of that due to stations, lots and first order interaction. Where the residual variance is the greater, no F ratio is shown, there being no question of the insignificance of lot or station. The F value necessary is the number of times which the variance for station or lot must exceed that for error to indicate the existence of real differences between stations or lots.

In Table 4 the average figures for each lot are given for each item recorded during these tests. In the last column is given the difference between the averages of any two lots, which it is considered might occur as a result of chance sampling of the pigs. Differences greater than these values are probably (odds of 19 to 1) expressive of real differences between the rations. Care should be taken in comparing lots fed during different years, however, since in some cases, as with corn for example, the feed samples of what appear to be replicate lots were different in feeding value.

Detail of the method of computing "Carcass Score" is given in Appendix Table 2. In this method "Area of Loin Muscle" refers to the calculated surface area of a cross section of the right *Longissimus dorsi* muscle made at the last full rib. This cross section is roughly oval in shape and the surface area is calculated as the product of the length (longest linear measurement) by the greatest width at right angles to the length.

DISCUSSION

Discussion of the results of these tests may, in the interests of clarity, be arranged chiefly under two general headings: (1) rate of gain and ration efficiency, (2) carcass excellence. It may, however, first be pointed out that the uniformity and similarity of the lots shown in Tables 3 and 4 with respect to such items as initial age, shipping weight and total gain are merely indicative of how closely the several stations were able to follow the plan of procedure. In no case are they such as to complicate the interpretations of the ration values.

TABLE 3.—MEANS AND STANDARD DEVIATIONS OF ITEMS RECORDED IN FEEDING TESTS

Item	Mean	σ	Coefficient of variability, %	*F values	
				Between lots	Between stations
Initial age (days)	71	3.7	5	—	8.5
Initial weight (lb.)	42	6.3	15	—	40.0
Days fed (days)	115	12.7	11	8.3	16.4
Daily feed (lb.)	5.1	.31	6	15.6	14.8
Shipping weight (lb.)	205	9.9	5	1.3	5.5
Total gain (lb.)	163	10.5	6	1.6	18.4
Daily gain (observed) (lb.)	1.4	.15	10	11.7	15.9
Daily gain (corrected) (lb.)	1.4	.12	9	—	—
Carcass score (%)	73	9.2	12	7.8	5.8
Carcass weight (lb.)	151	8.3	5	4.5	3.3
Carcass length (in.)	30.4	0.8	3	1.8	2.0
Percentage shoulder (%)	29	1.1	4	6.4	12.6
Percentage middle (%)	47	1.5	3	9.1	14.4
Percentage ham (%)	24	.9	4	6.4	14.2
Shoulder fat (in.)	1.9	.21	11	6.6	16.6
Back fat (in.)	1.1	.18	16	9.4	10.7
Loin fat (in.)	1.4	.18	13	13.4	10.4
Fat evenness (in.)	.8	.19	24	2.2	10.1
Max. belly thickness (in.)	1.6	.20	13	5.6	23.4
Min. belly thickness (in.)	.8	.14	18	4.9	48.8
Area of loin muscle (sq. in.)	5.5	.59	14	6.1	43.4

* F values greater than 1.92 or 2.41 indicate that there are real differences between lots or between stations respectively.

From the Means shown in Table 3 a general picture of the progress of the trials may be obtained. Daily gains were 1.4 pounds with very low variability between the individual pigs within the ration groups. Taking all pigs, the carcass scores average 73% which, though just below the minimum (75) for advanced registry qualifications, indicate a very satisfactory type of pig when allowance is made for the damaging effect of certain of the rations as seen later.

It is interesting to note that the type of pig differs from station to station (*i.e.* F values greater than 2.41 for station) other than for length of carcass. It is significant that in spite of such differences the reactions to the different rations were the same at all stations. This consistency between stations of course increases the dependence which can be placed on the observed ration effects. These are summarized in Table IV.

Rate of Gain and Ration Efficiency

The effect of ration on rate of gain and on ration efficiency is indicated in Table 4 by the days of feeding necessary to bring the pigs to market weight, and by the calculated average daily gain. The gains, adjusted to remove the effect of differing feed intake, are more frequently used for direct comparison than are the observed gains.

The effect of oats is perhaps the first to be noted. As compared to high grade barley (columns 1 and 2) oats markedly depresses rate of gain. Complete substitution of oats for barley lengthened the necessary feeding

TABLE 4.—SUMMARY OF RESULTS SHOWING AVERAGE LOT VALUES

Items	1937 Tests					1938 Tests					Nec. Diff.
	Lot I	Lot II	Lot III	Lot IV	Lot V	Lot VI	Lot VII	Lot VIII	Lot IX	Lot X	
	Barley 3 C.W. Feed	Oats	Corn	Barley Oats	Corn Oats	Barley No. 1 Feed	Barley No. 2 Feed	Barley No. 3 Feed	Corn	Barley Oats	P = 0.05
Number of hogs	25	25	25	25	25	25	25	25	25	25	
Initial age (days)	70	71	70	71	70	72	71	72	72	71	2
Initial weight (lb.)	43	43	43	44	43	42	40	42	41	41	3
Days fed (days)	106	129	113	116	114	109	108	114	127	114	7
Total feed eaten (lb.)	598	631	626	618	624	562	566	582	550	572	—
Daily feed (lb.)	5.5	4.8	5.4	5.2	5.3	5.1	5.1	5.0	4.8	5.0	0.2
Shipping weight (lb.)	205	202	208	205	206	208	206	208	202	206	5
Total gain (lb.)	162	158	165	161	162	166	165	166	161	165	6
Daily gain (observed) (lb.)	1.54	1.24	1.47	1.40	1.43	1.54	1.54	1.47	1.30	1.46	0.08
Daily gain (corrected) (lb.)	1.46	1.30	1.43	1.39	1.42	1.54	1.54	1.49	1.37	1.48	0.08
Carcass score (%)	75	71	68	74	73	80	80	75	63	73	5
Carcass weight (lb.)	152	145	158	147	150	153	151	151	153	151	6
Carcass length (in.)	30.3	30.5	30.2	30.3	30.3	30.6	30.6	30.6	29.9	30.6	0.5
Percentage shoulders (%)	28	30	28	29	29	28	28	28	28	29	0.6
Percentage middles (%)	48	45	48	47	47	48	48	48	49	47	0.8
Percentage hams (%)	24	25	24	24	24	24	24	24	23	24	0.5
Shoulder fat (in.)	1.9	1.7	2.1	1.8	1.9	1.8	1.9	1.9	2.1	1.8	0.1
Back fat (in.)	1.1	.9	1.3	1.0	1.0	1.1	1.1	1.1	1.2	1.0	0.1
Loin fat (in.)	1.4	1.2	1.7	1.3	1.4	1.5	1.4	1.4	1.6	1.4	0.1
Fat evenness (in.)	0.8	0.9	0.8	0.8	0.8	0.7	0.7	0.8	0.9	0.8	0.1
Max. belly thickness (in.)	1.6	1.4	1.7	1.6	1.6	1.6	1.6	1.5	1.7	1.6	0.1
Min. belly thickness (in.)	0.8	0.7	0.8	0.7	0.7	0.8	0.8	0.8	0.9	0.8	0.1
Area loin muscle (sq. in.)	5.9	5.6	5.4	5.8	5.4	5.4	5.5	5.7	4.5	5.7	0.4
Percentage lean in rasher (%)	44	48	39	46	40	41	41	44	31	45	4

period about 3 weeks and reduced gains by 0.25 pound per day. A large part of this effect is evidently the result of smaller feed consumption, for when this latter is "held constant" the adjusted gain rate is less adversely affected.

It will be surprising to some that rate of gain on high grade barley is fully equal to that made on corn rations. Indeed in these trials barley diluted with 17% wild oats competes favourably with the corn in this respect. As already noted the corn used was South African grown. That fed during the 1938 trials appeared to have soured in the case of the Ontario Agricultural College test, and it was necessary to discard the ration and substitute another prepared from Ontario corn. The 1938 corn ration was also not relished by the pigs in the two tests at Macdonald College. Thus the gains on the corn ration in 1938 are lower than expected. No such difficulty was experienced with the 1937 corn lots. The comparative gains and carcass characteristics nevertheless showed the corn-fed pigs to be inferior to those fed the top grades of barley.

The effect of diluting barley with wild oats is indicated in the comparisons of lots fed No. 1, No. 2 and No. 3 barley. These "barleys" carried 3%, 8% and 17% respectively of wild oats. Evidently up to 8% wild oats has had no measurable effect. The No. 3 barley ration carrying 17% wild oats, however, produced slower gains, a week longer feeding period being required to finish the hogs than in the case of the better grades of barley. Indeed 17% wild oats in the high grade barley appeared to have about the same deleterious effect on gains as did 50% of domestic oats. In other words, in these tests the "dilution" effect of wild oats was three times that of No. 3 Canadian Western oats. The results to be expected when not only the presence of the wild oats but also a light weight barley is involved in the lower feed grade (*i.e.* No. 3 barley) have already been mentioned.

Carcass Excellence

There is some evidence (McMeekan, C. P., 7) that rate of gain may be an important factor in determining the fat-lean-bone ratio of the hog carcass. In general, rapid early gains tend to result in greater lean development. Obviously other factors than leanness may influence carcass excellence and the carcass score is intended as a general measure of such excellence. It is based on a standard of excellence, details of which are given in Appendix Table 2. It is enough to point out here that length, weight, finish, balance, and leanness of the carcass (as measured by area of cross section of loin muscle) are all considered.

In so far as the Canadian producer of bacon is concerned carcass excellence is usually of greater significance than minor differences in rate of gain or feed efficiency. In these tests it is in carcass quality that the greatest effect of corn is seen. Not only is the score significantly lower but there was a tendency for corn-fed pigs to show less desirable fat-lean patterns in the cut rasher. A smaller "eye of lean" or "pork chop muscle" was found together with a tendency for too heavy a fat layer. In studying the "area of loin muscle" (or any other) figures in Table 4, comparisons within the same year will be uncomplicated with differences between years. We note that corn appears to depress not only the percentage lean in the bacon rasher but also the absolute quantity of the lean in the rasher (See Table 5).

TABLE 5.—EFFECT OF CORN ON LEAN OF BACON RASHER

Measurement	Year	High grade Barley	Corn	Difference
Estimated area loin muscle	1937	5.9 sq. in.	5.4 sq. in.	−0.5 sq. in.
Estimated area loin muscle	1938	5.4 sq. in.	4.5 sq. in.	−0.9 sq. in.
*Percentage lean in rasher	1937	44%	39%	− 5%
*Percentage lean in rasher	1938	41%	31%	−10%

* 50 pigs from Macdonald College tests.

As seen from the carcass measurements this effect is largely responsible for the poorer carcass score for the corn-fed hogs, and is an important consideration in the Canadian bacon industry.

Typical rasher surfaces for the corn-fed and the barley-fed hogs are shown in Figure 1. Tracings of the rashers of the 50 hogs fed in the Macdonald College 1938 tests are found in the appendix. From these tracings and from the detailed carcass measurements it is evident that corn has produced a thicker, fatter carcass than barley, while the oat-fed pigs yielded the leanest, but frequently under finished carcasses. Between the several rations containing barley there was apparently nothing to choose in so far as carcass characteristics are concerned.

Fat Firmness

The effect of corn on the firmness of fat is not included in the table of lot averages. For the 50 pigs fed at Macdonald College during 1937, iodine numbers were run with results as follows:

Lot	*Ration*	*Average Iodine Number*
I	Barley	57
II	Oats	61
III	Corn	62
IV	Barley + Oats	57
V	Corn + Oats	59

The variability of the values for the individual pigs on the same feed is measured by a standard deviation of 2.01 units. If we demand a reliability of 95%, then it may be calculated that unless the average iodine numbers in the above table differ by more than 1.8 units no great dependence should be placed on the differences. On this basis both corn and oats have produced softer carcasses than barley. The iodine number alone, however, does not have much practical significance without some key relating a given iodine number to some accepted standard of fat firmness. For routine use in grading carcasses under the Canadian Advanced Registry Scheme for Swine, fat firmness is judged by the grader largely on the basis of its hardness to thumb pressure and a carcass is described under one of the following headings:

V.S.—very soft; S.—soft; S.S—slightly soft; F.F.—fairly firm; F.—firm; V.F.—very firm.

For all carcasses the "thumb test" for fat firmness was recorded. This index of course may be influenced by the temperature of the cooler and by differing judgment of operators at different packing plants. For practical purposes it has been found useful for ordinary carcass grading purposes. For purposes of this project the six classes into which firmness was graded were given numerical values from 1 for the softest to 6 for the hardest fat. The resulting numbers were then averaged by lots and by stations.

The averages for the ten different ration groups are shown in Table 6.

TABLE 6.—FIRMNESS OF FAT PRODUCED BY DIFFERENT RATIONS

Lot	Year	Average firmness index	Class of fat thumb test	Iodine number
I No. 3 C.W. Barley	1937	5.3	Firm +	57
II No. 3 C.W. Oats	1937	4.8	Firm −	61
III Yellow corn	1937	4.7	Firm −	62
IV Barley + oats	1937	5.0	Firm	57
V Corn + oats	1937	5.2	Firm +	59
VI Barley + 3% wild oats	1938	5.5	Firm +	—
VII Barley + 7% wild oats	1938	5.4	Firm +	—
VIII Barley + 17% wild oats	1938	5.2	Firm +	—
IX Yellow corn	1938	4.6	Firm −	—
X Barley + oats	1938	5.0	Firm	—
Average	—	5.1	—	59

It is evident from this grading that corn and oats have about equal softening effects on the carcass. It may be estimated roughly that the average (1937) iodine number of 59 corresponds to the average class index of 5, Firm, and that a change of about 5 units in iodine number is equivalent to a change of 1 grade in fat firmness.

Thus while both corn and oats have produced carcasses which grade one class softer than those produced on barley, all of the rations have resulted in carcasses averaging Firm, and presumably therefore satisfactory in this respect.

Before leaving this discussion it should be mentioned in fairness to corn as a hog feed, that these tests do not establish nor indeed indicate that this feed has no place in the Canadian hog ration. It is quite evident, however, that where corn constitutes the entire basal feed in the ration, carcasses inferior to those expected from barley-fed hogs are to be anticipated. Nevertheless in these trials a mixed corn and oats ration yielded a satisfactory bacon carcass, from which it may be argued that corn might constitute up to 50% of the basal feed in the market hog ration without risk of serious penalty in carcass quality.

Actually, the important finding from these studies is not that corn may be damaging to bacon carcass excellence, but rather that barley, a Canadian grown feed, is fully equal to corn as a hog feed. This difference does exist, however, that pure barley may satisfactorily constitute the entire basal feed of the bacon hog while the use of corn in this way has resulted in inferior bacon carcasses in these tests.

CONCLUSIONS

1. Barley conforming in purity with 1939 standards of the Canada Grain Act for Canadian Western No. 1 feed barley is superior as a bacon hog feed to corn or oats. This holds true whether rate of gain, efficiency of feed or carcass excellence is used as the measure.

2. The two top grades of Canadian Western feed barley appear practically equal in feeding value, but the presence of 17% of wild oats (lot VIII) largely destroys any advantage which the higher grades of barley have over corn excepting possibly in carcass quality.

3. While producing slower gains, mixtures of equal parts of pure barley and domestic oats or corn and oats produced acceptable market carcasses. They were not, however, the equal of those from the pigs on pure barley rations.

4. The most serious effect of corn as the entire basal ration was seen in carcass excellence. Associated with the heavy corn feeding were bacon rashers having smaller lean areas both absolutely and in percentage, as well as a less desirable fat-lean pattern.

5. Oats when constituting the entire basal fraction of the hog ration produced much slower gains in live weight. The carcasses from oat fed hogs carried a high percentage of lean, but were under finished and hence less desirable than those from barley or barley and oat fed hogs.

6. High grade barley may constitute the entire basal part of the ration of pigs from weaning to market weight provided a satisfactory protein-mineral-vitamin supplement is used to balance the ration. Corn cannot be thus freely used without penalty in the excellence of the carcasses produced as measured by Canadian bacon standards.

7. The chief effect of the presence in the barley ration of either wild or domestic oats is to reduce the rate of gain of the pigs. In these tests inclusion of 17% wild oats had about the same effect on rate of gain as 50% domestic oats (No. 3 C.W. oats).

ACKNOWLEDGMENTS

The data herein reported represent the results of a co-operative project undertaken for the purpose of establishing the relative feeding value for bacon hogs of Canadian Western barley. The project was made possible through the co-operation of several organizations who have contributed directly or indirectly to the expense involved.

While it is not possible to estimate accurately the total costs of the project or the share borne by any one organization, the general arrangement was as follows:

The Western Canadian Wheat Pools have borne the cost of all of the feed used at three of the stations, and that of the barley at the other two stations. The cutting, measuring, and grading of the carcasses were undertaken by the Marketing Service of the Dominion Department of Agriculture. The losses resulting from the cutting of the carcasses were borne by Canada Packers Ltd. and Wilsils Ltd. These organizations also furnished labour and cooler facilities needed in the carcass studies. The Dominion Experimental Farms system,

Footnote 1, first page,—page 365.

the Ontario Agricultural College, and Macdonald College (McGill University) have borne the other costs of the tests at their respective stations including the animals used and time of technical staffs. The Dominion Department of Agriculture has contributed toward the cost of the statistical analysis of the data and the preparation of the manuscript for the reports. They further published and distributed the Interim Reports of the tests.

There are others whose time and advice have been used on numerous occasions during the two years the work has been under way. Dr. J. W. Hopkins of the National Research Council, and Professor R. Summerby of Macdonald College have been of help in connection with the methods of statistical analysis. Thanks are also due Mr. G. C. Ashton, Assistant in Animal Experimentation at Macdonald College, under whose immediate supervision the laborious statistical analyses have been carried out.

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APPENDIX

Table 1a. Chemical Analysis of Rations by Stations (1937 Tests).
  a. Weaning period rations.
  b. Fattening period rations.
Table 1b. Chemical Analysis of Rations by Stations (1938 Tests).
  a. Weaning period rations.
  b. Fattening period rations.
Table 1c. Chemical Analysis of Individual Feeds (1938 only).
Table 2. Standard of Carcass Score for Swine.
Tables 3–24. Analysis of Variance of Items Recorded During Tests.
Figures 2–6. Bacon Rasher Patterns from Pigs on 1938 Rations.

Key to Stations—
A — Test 1, Macdonald College, Que.
B — Test 2, Macdonald College, Que.
C — Dominion Experimental Farm, Nappan, N.S.
D — Dominion Experimental Station, Ste. Anne de la Pocatiere, Que.
E — Ontario Agricultural College, Guelph, Ont.

APPENDIX TABLE 1A.—CHEMICAL ANALYSIS OF RATIONS BY STATIONS, 1937
(MOISTURE FREE BASIS)

Ration	Station	Crude protein	Crude fat	Crude fibre	Ash	N-free extract
Rations (A)						
Barley	Mac. College	20.67	3.34	6.65	7.10	62.24
	Ste. Anne	21.08	3.38	6.68	7.60	61.26
	Nappan	21.72	3.65	6.10	7.20	61.33
	O.A.C.	21.20	3.61	6.63	6.90	61.66
	Average	21.16	3.49	6.51	7.20	61.62
Oats	Mac. College	17.99	3.74	11.69	9.30	57.28
	Ste. Anne	18.53	3.68	12.79	9.90	55.10
	Nappan	18.38	3.98	12.44	9.50	55.70
	O.A.C.	18.06	4.18	11.48	8.50	57.78
	Average	18.24	3.89	12.10	9.30	56.46
Corn	Mac. College	17.68	5.70	2.45	6.30	67.87
	Ste. Anne	17.26	6.24	2.28	6.10	68.12
	Nappan	17.72	5.98	2.24	5.70	68.36
	O.A.C.	17.70	6.17	2.42	6.10	67.61
	Average	17.59	6.02	2.35	6.00	67.99
Barley + Oats	Mac. College	20.28	3.58	9.23	8.60	58.31
	Ste. Anne	19.51	3.99	9.27	8.80	58.43
	Nappan	20.05	4.22	9.23	8.20	58.30
	O.A.C.	19.85	4.03	9.34	8.10	58.68
	Average	19.92	3.95	9.27	8.40	58.43
Corn + Oats	Mac. College	18.57	3.20	6.74	7.60	63.89
	Ste. Anne	17.73	5.36	7.02	8.50	61.39
	Nappan	17.89	5.62	6.89	9.30	60.30
	O.A.C.	18.84	5.00	6.42	8.70	61.04
	Average	18.26	4.79	6.77	8.50	61.65
Rations (B)						
Barley	Mac. College	18.59	2.89	6.93	5.40	66.19
	Ste. Anne	20.35	3.44	6.50	6.20	63.51
	Nappan	19.81	2.86	6.40	6.30	64.64
	O.A.C.	19.33	3.35	6.65	5.60	65.07
	Average	19.52	3.13	6.62	5.90	64.85
Oats	Mac. College	15.97	4.77	12.69	9.00	57.57
	Ste. Anne	16.20	4.69	14.00	8.80	56.30
	Nappan	16.42	4.98	12.89	9.40	56.30
	O.A.C.	16.18	5.35	13.72	8.30	56.48
	Average	16.19	4.95	13.32	8.90	56.66
Corn	Mac. College	16.68	5.48	2.18	5.00	70.65
	Ste. Anne	15.74	5.73	2.66	5.30	70.58
	Nappan	16.38	6.05	2.49	5.20	69.89
	O.A.C.	15.18	6.22	2.66	4.80	71.14
	Average	15.99	5.87	2.50	5.10	70.56
Barley + Oats	Mac. College	17.68	3.95	9.00	7.20	62.18
	Ste. Anne	17.78	4.16	9.96	7.30	60.80
	Nappan	17.48	4.69	9.70	6.80	61.31
	O.A.C.	18.68	4.73	9.65	7.10	59.84
	Average	17.90	4.38	9.58	7.10	61.03
Corn + Oats	Mac. College	15.27	5.06	6.73	7.10	65.85
	Ste. Anne	15.50	5.15	7.27	6.30	65.78
	Nappan	15.92	4.73	7.48	6.60	65.27
	O.A.C.	16.50	5.27	7.00	6.70	64.53
	Average	15.80	5.05	7.12	6.70	65.36

APPENDIX TABLE 1B.—CHEMICAL ANALYSIS OF RATIONS BY STATIONS, 1938

(MOISTURE FREE BASIS)

Ration	Station	Crude protein	Crude fat	Crude fibre	Ash	N-free extract
Rations (A)						
Barley No. 1 Feed	Mac. College	20.36	3.54	6.54	8.32	61.24
	Ste. Anne	19.64	3.91	6.32	8.25	61.88
	Nappan	20.09	4.17	5.85	7.33	62.57
	O.A.C.	19.81	2.92	6.53	7.89	62.85
	Average	19.97	3.63	6.31	7.95	62.13
Barley No. 2 Feed	Mac. College	20.13	3.31	6.69	7.19	62.67
	Ste. Anne	20.21	4.27	6.44	8.21	60.87
	Nappan	20.03	4.50	6.18	7.73	61.56
	O.A.C.	19.66	4.36	7.06	7.80	61.12
	Average	20.01	4.11	6.59	7.73	61.55
Barley No. 3 Feed	Mac. College	19.73	3.55	7.50	6.79	62.43
	Ste. Anne	18.55	4.05	7.32	8.19	61.89
	Nappan	16.96	4.11	7.74	6.81	64.39
	O.A.C.	20.19	4.36	7.62	7.18	60.65
	Average	18.86	4.02	7.54	7.24	62.34
Corn	Mac. College	16.48	5.55	2.57	5.87	69.53
	Ste. Anne	17.11	5.98	2.55	7.87	66.48
	Nappan	16.81	6.36	2.77	6.46	67.61
	O.A.C.	16.83	6.08	2.66	6.73	67.71
	Average	16.81	5.99	2.64	6.73	67.83
Barley + Oats	Mac. College	19.25	4.18	9.54	7.52	59.51
	Ste. Anne	22.32	5.03	8.38	8.51	55.75
	Nappan	22.04	5.09	8.19	8.62	56.05
	O.A.C.	19.29	4.09	9.26	7.41	59.95
	Average	20.72	4.60	8.84	8.01	57.81
Rations (B)						
Barley No. 1 Feed	Mac. College	18.76	3.37	6.44	5.87	65.56
	Ste. Anne	18.34	3.59	6.19	5.97	65.90
	Nappan	18.27	4.05	6.18	6.50	65.01
	O.A.C.	17.88	4.10	6.00	6.12	65.90
	Average	18.31	3.78	6.20	6.12	65.59
Barley No. 2 Feed	Mac. College	18.95	3.43	6.90	5.84	64.89
	Ste. Anne	18.21	3.92	6.77	5.92	65.17
	Nappan	18.30	3.18	7.24	6.63	64.65
	O.A.C.	17.62	4.47	6.49	5.74	65.67
	Average	18.27	3.75	6.85	6.03	65.09
Barley No. 3 Feed	Mac. College	17.86	3.65	7.99	5.49	65.01
	Ste. Anne	18.20	4.08	8.26	5.96	63.50
	Nappan	18.25	3.78	7.95	6.59	63.43
	O.A.C.	17.84	3.59	7.74	5.88	64.95
	Average	18.04	3.78	7.98	5.98	64.22
Corn	Mac. College	15.48	5.18	2.39	4.31	72.64
	Ste. Anne	14.49	5.93	2.55	4.86	72.17
	Nappan	14.87	5.43	2.61	4.97	72.12
	O.A.C.	14.70	5.74	2.63	4.71	72.21
	Average	14.88	5.57	2.54	4.71	72.28
Barley + Oats	Mac. College	18.03	4.75	8.92	5.44	62.85
	Ste. Anne	17.88	4.57	9.28	6.27	62.00
	Nappan	18.55	4.01	8.74	6.63	62.06
	O.A.C.	18.13	4.96	8.50	6.27	62.13
	Average	18.15	4.57	8.86	6.15	62.26

APPENDIX TABLE 1c.—CHEMICAL ANALYSIS OF INDIVIDUAL FEEDS, 1938
(MOISTURE FREE BASIS)

Feed	Factor	Crude protein	Crude fat	Crude fibre	Ash	N-free extract
Barley	88.25	14.69	2.42	6.07	3.17	73.64
Corn	87.58	10.96	5.34	2.41	2.09	79.20
Oats	87.45	13.26	5.76	12.74	3.72	64.52
Screenings	89.37	16.65	9.71	17.25	7.94	48.44
Black Oats	88.78	14.76	5.81	15.41	4.80	59.22
Tankage	90.42	68.40	9.12	2.23	19.58	.66
Linseed oilmeal	89.92	45.76	6.92	7.42	5.72	34.19
Fishmeal	90.98	74.85	2.54	.32	26.06	—
Bonemeal	95.92	17.54	5.94	3.38	73.01	.14

APPENDIX TABLE 2.—STANDARD OF CARCASS SCORE FOR SWINE

	Points	Carcass weights (cold)				
			A-1 weight			
		125 – 135	135 – 145	145 – 155	155 – 165	165 – 175
			Carcass length			
Minimum	20	29.5	30.0	30.5	31.0	31.5
	15	29.0	29.5	30.0	30.5	31.0
	10	28.5	29.0	29.5	30.0	30.5
	5	28.0	28.5	29.0	29.5	30.0
Maximum	20	31.5	32.0	32.5	33.0	33.5
	15	32.0	32.5	33.0	33.5	34.0
	10	32.5	33.0	33.5	34.0	34.5
	5	33.0	33.5	34.0	34.5	35.0
		Back fat				
Maximum	6	1.7	1.8	1.9	2.0	2.1
	4	1.8	1.9	2.0	2.1	2.2
	2	1.9	2.0	2.1	2.2	2.3
Minimum	6	.8	0.9	1.0	1.1	1.2
	4	.7	.8	.9	1.0	1.1
	2	.6	.7	.8	.9	1.0
Max. Diff.	8	.7	.7	.7	.7	.7
	6	.8	.8	.8	.8	.8
	4	.9	.9	.9	.9	.9
	2	1.0	1.0	1.0	1.0	1.0

	Balance of side		
	Ham	Middle	Shoulder
7	26	50	25
6	25	49	26
5	24	48	27
4	23	47	28
3	22	46	29
2	21	45	30
1	20	44	31

APPENDIX TABLE 2.—STANDARD OF CARCASS SCORE FOR SWINE—*Concluded*

Points	Carcass weights (cold)				
		A-1 weight			
	125 – 135	135 – 145	145 – 155	155 – 165	165 – 175
		Area of loin muscle			
20	5.00	5.25	5.50	5.75	6.00
18	4.75–4.99	5.00–5.24	5.25–5.49	5.50–5.74	5.75–5.99
16	4.50–4.74	4.75–4.99	5.00–5.24	5.25–5.49	5.50–5.74
14	4.25–4.49	4.50–4.74	4.75–4.99	5.00–5.24	5.25–5.49
12	4.00–4.24	4.25–4.49	4.50–4.74	4.75–4.99	5.00–5.24
10	3.75–3.99	4.00–4.24	4.25–4.49	4.50–4.74	4.75–4.99
8	3.50–3.74	3.75–3.99	4.00–4.24	4.25–4.49	4.50–4.74
6	3.25–3.49	3.50–3.74	3.75–3.99	4.00–4.24	4.25–4.49
4	3.00–3.24	3.25–3.49	3.50–3.74	3.75–3.99	4.00–4.24
	Belly Grade				
20	E – G	E	E	E	
18		G			E
16			G		
14	F			G	
12		F			G
10			F		
8	P			F	
6		P			F
4			P		
2				P	
0					P

APPENDIX TABLE 3.—INITIAL AGE

Lot and Station Averages—1937 and 1938

Station	Barley 3 C.W. Feed 1937	Barley 1 C.W. Feed 1938	Barley 2 C.W. Feed 1938	Barley 3 C.W. Feed 1938	Barley Oats 1937	Barley Oats 1938	Oats 1937	Corn 1937	Corn 1938	Corn Oats 1937	Station averages
A	72	73	75	75	72	72	74	73	74	73	73.3
B	72	71	68	70	75	71	76	71	71	72	71.8
C	69	73	73	73	69	72	67	69	73	69	70.7
D	69	70	70	70	69	71	69	69	70	69	69.5
E	69	72	69	72	70	68	69	68	71	69	69.8
Lot averages	70.2	71.9	71.0	72.2	71.0	70.8	70.9	70.0	71.8	70.4	71.0

Analysis of Variance

Description	D/F	$S(x-\bar{x})^2$	σ^2	σ	F values		$C.V.$
					Observed	Necessary	%
Total	249	4025.74					
Between sub-classes	49	1210.14					
Between lots	9	114.94	12.77		—	—	
Between stations	4	477.86	119.47		8.49	2.41	
Interaction	36	617.34	17.15		1.22	1.45	
Calculated values	0						
Remainder	200	2815.60	14.08	3.75			5.28

Necessary difference between lot means $= \frac{3.75}{\sqrt{25}} \times \sqrt{2} \times 1.96 = 2.08.$

Necessary difference between stations means $= \frac{3.75}{\sqrt{50}} \times \sqrt{2} \times 1.96 = 1.47.$

Appendix Table 4.—Initial weight

Lot and Station Averages—1937 and 1938

Station	Barley 3 C.W. Feed 1937	Barley 1 C.W. Feed 1938	Barley 2 C.W. Feed 1938	Barley 3 C.W. Feed 1938	Barley Oats 1937	Barley Oats 1938	Oats 1937	Corn 1937	Corn 1938	Corn Oats 1937	Station averages
A	38.4	32.8	28.2	31.0	39.0	31.4	40.0	43.2	31.4	40.6	35.6
B	39.8	33.0	36.4	37.0	40.8	35.4	45.4	38.8	35.4	36.6	37.9
C	47.0	49.4	47.4	48.4	46.2	48.2	46.0	46.6	45.8	45.6	47.1
D	47.2	52.2	50.2	50.0	45.8	52.0	44.0	45.4	52.4	46.0	48.5
E	43.2	40.6	40.4	41.4	47.2	40.4	41.2	43.0	40.8	48.2	42.6
Lot averages	43.1	41.6	40.5	41.6	43.8	41.5	43.3	43.4	41 2	43.4	42.3

Analysis of Variance

Description	D/F	$S(x - \bar{x})^2$	σ^2	σ	F values		$C.V.$
					Observed	Necessary	%
Total	249	16833.78					
Between sub-classes	49	8953.38					
Between lots	9	313.70	34.85		—	—	
Between stations	4	6302.94	1575.73		39.99	2.41	
Interaction	36	2336.74	64.91		16.47	1.45	
Calculated values	0						
Remainder	200	7880.40	39.40	6.28			14.82

Necessary difference between lot means $= \frac{6.28}{\sqrt{25}} \times \sqrt{2} \times 1.96 = 3.48.$

Necessary difference between station means $= \frac{6.28}{\sqrt{50}} \times \sqrt{2} \times 1.96 = 2.46.$

Appendix Table 5.—Days fed to market

Lot and Station Averages—1937 and 1938

Station	Barley 3 C.W. Feed 1937	Barley 1 C.W. Feed 1938	Barley 2 C.W. Feed 1938	Barley 3 C.W. Feed 1938	Barley Oats 1937	Barley Oats 1938	Oats 1937	Corn 1937	Corn 1938	Corn Oats 1937	Station averages
A	108	113	116	123	113	123	136	112	136	121	120.2
B	102	116	109	116	115	112	122	118	146	116	117.2
C	106	103	102	105	115	105	126	104	113	116	109.6
D	101	93	97	101	113	98	128	117	107	101	105.7
E	114	118	118	126	124	133	132	117	132	118	123.1
Lot averages	106.3	108.8	108.5	114.4	116.0	114.3	128.8	113.5	126.7	114.5	115.2

Analysis of Variance

Description	D/F	$S(x - \bar{x})^2$	σ^2	σ	F values		$C.V.$
					Observed	Necessary	%
Total	249	62932.90					
Between sub-classes	49	30732.10					
Between lots	9	12198.82	1355.41		8.33	1.92	
Between stations	4	10679.48	2669.87		16.42	2.41	
Interaction	36	7853.80	218.16		1.34	1.45	
Calculated values	2						
Remainder	198	32200.80	162.63	12.75			11.07

Necessary difference between lot means $= \frac{12.75}{\sqrt{25}} \times \sqrt{2} \times 1.96 = 7.07.$

Necessary difference between station means $= \frac{12.75}{\sqrt{50}} \times \sqrt{2} \times 1.96 = 5.00.$

APPENDIX TABLE 6.—DAILY FEED (TO MARKET)

Lot and Station Averages—1937 and 1938

Station	Barley 3 C.W. Feed 1937	Barley 1 C.W. Feed 1938	Barley 2 C.W. Feed 1938	Barley 3 C.W. Feed 1938	Barley Oats 1937	Barley Oats 1938	Oats 1937	Corn 1937	Corn 1938	Corn Oats 1937	Station averages
A	5.67	5.24	5.09	4.91	5.47	4.98	4.72	5.47	4.71	4.87	5.13
B	5.84	4.97	5.16	4.97	5.51	5.08	4.83	5.35	4.59	5.40	5.18
C	5.55	5.24	5.28	5.17	5.12	5.12	5.01	5.62	4.94	5.22	5.23
D	5.55	5.35	5.28	5.23	5.16	5.20	4.75	5.30	4.94	5.68	5.24
E	5.14	4.92	4.86	4.82	4.68	4.69	4.50	5.14	4.62	4.88	4.83
Lot averages	5.55	5.15	5.13	5.02	5.19	5.01	4.76	5.38	4.76	5.27	5.12

Analysis of Variance

Description	D/F	$S(x - \bar{x})^2$	σ^2	σ	F values		$C.V.$
					Observed	Necessary	%
Total	249	154.69					
Between sub-classes	49	135.11					
Between lots	9	13.90	1.54		15.62	1.92	
Between stations	4	5.84	1.46		14.77	2.41	
Interaction	36	115.36	3.20		32.41	1.45	
Calculated values	2						
Remainder	198	19.58	.10	.31			6.14

Necessary difference between lot means $= \frac{0.31}{\sqrt{25}} \times \sqrt{2} \times 1.96 = 0.17.$

Necessary difference between station means $= \frac{0.31}{\sqrt{50}} \times \sqrt{2} \times 1.96 = 0.12.$

APPENDIX TABLE 7.—SHIPPING WEIGHT

Lot and Station Averages—1937 and 1938

Station	Barley 3 C.W. Feed 1937	Barley 1 C.W. Feed 1938	Barley 2 C.W. Feed 1938	Barley 3 C.W. Feed 1938	Barley Oats 1937	Barley Oats 1938	Oats 1937	Corn 1937	Corn 1938	Corn Oats 1937	Station averages
A	208	214	203	203	207	209	206	211	201	204	206.7
B	208	199	205	203	214	203	199	210	207	212	206.1
C	210	214	213	213	204	207	213	208	205	209	209.6
D	202	206	207	211	201	206	201	209	200	204	204.8
E	200	206	201	210	196	205	196	203	197	199	200.6
Lot averages	205.5	207.9	205.9	207.8	204.6	206.1	204.6	208.3	202.0	205.6	205.5

Analysis of Variance

Description	D/F	$S(x - \bar{x})^2$	σ^2	σ	F values		$C.V.$
					Observed	Necessary	%
Total	249	26297.92					
Between sub-classes	49	6810.72					
Between lots	9	1134.48	126.05		1.28	1.92	
Between stations	4	2158.66	539.67		5.48	2.41	
Interaction	36	3517.58	97.71		—	—	
Calculated values	2						
Remainder	198	19487.20	98.42	9.92			4.83

Necessary difference between lot means $= \frac{9.92}{\sqrt{25}} \times \sqrt{2} \times 1.96 = 5.50.$

Necessary difference between station means $= \frac{9.92}{\sqrt{50}} \times \sqrt{2} \times 1.96 = 3.88.$

APPENDIX TABLE 8.—TOTAL GAIN (TO MARKET)

Lot and Station Averages—1937 and 1938

Station	Barley 3 C.W. Feed 1937	Barley 1 C.W. Feed 1938	Barley 2 C.W. Feed 1938	Barley 3 C.W. Feed 1938	Barley Oats 1937	Barley Oats 1938	Oats 1937	Corn 1937	Corn 1938	Corn Oats 1937	Station averages
A	170	182	175	172	168	177	166	167	170	164	171.1
B	168	166	169	166	174	168	154	172	171	175	168.2
C	163	164	166	164	158	159	167	162	158	164	162.4
D	155	154	157	161	156	154	157	164	148	158	156.3
E	157	165	161	168	149	165	148	160	156	151	157.9
Lot averages	162.4	166.3	165.4	166.1	160.8	164.6	158.5	164.9	160.6	162.2	163.2

Analysis of Variance

Description	D/F	$S(x - \bar{x})^2$	σ^2	σ	F values		$C.V.$
					Observed	Necessary	%
Total	249	36752.26					
Between sub-classes	49	14690.26					
Between lots	9	1594.82	177.20		1.59	1.92	
Between stations	4	8181.38	2045.34		18.36	2.41	
Interaction	36	4914.06	136.50		1.22	1.45	
Calculated values	2						
Remainder	198	22062.00	111.42	10.56			6.47

Necessary difference between lot means $= \frac{10.56}{\sqrt{25}} \times \sqrt{2} \times 1.96 = 5.85.$

Necessary difference between station means $= \frac{10.56}{\sqrt{50}} \times \sqrt{2} \times 1.96 = 4.14.$

APPENDIX TABLE 9.—DAILY GAIN (TO MARKET)

Lot and Station Averages—1937 and 1938

Station	Barley 3 C.W. Feed 1937	Barley 1 C.W. Feed 1938	Barley 2 C.W. Feed 1938	Barley 3 C.W. Feed 1938	Barley Oats 1937	Barley Oats 1938	Oats 1937	Corn 1937	Corn 1938	Corn Oats 1937	Station averages
A	1.58	1.61	1.51	1.40	1.50	1.44	1.22	1.51	1.28	1.36	1.44
B	1.64	1.44	1.56	1.44	1.52	1.50	1.27	1.46	1.20	1.51	1.45
C	1.53	1.60	1.63	1.56	1.38	1.53	1.33	1.56	1.42	1.41	1.50
D	1.54	1.67	1.63	1.60	1.39	1.58	1.24	1.44	1.41	1.59	1.51
E	1.38	1.40	1.37	1.34	1.21	1.26	1.14	1.38	1.22	1.29	1.30
Lot averages	1.54	1.54	1.54	1.47	1.40	1.46	1.24	1.47	1.30	1.43	1.44

Analysis of Variance

Description	D/F	$S(x - \bar{x})^2$	σ^2	σ	F values		$C.V.$
					Observed	Necessary	%
Total	249	8.80					
Between sub-classes	49	4.51					
Between lots	9	2.28	.25		11.69	1.92	
Between stations	4	1.38	.34		15.92	2.41	
Interaction	36	.86	.02		1.10	1.45	
Calculated values	2						
Remainder	198	4.29	.02	.15			10.22

Necessary difference between lot means $= \frac{0.15}{\sqrt{25}} \times \sqrt{2} \times 1.96 = 0.08.$

Necessary difference between station means $= \frac{0.15}{\sqrt{50}} \times \sqrt{2} \times 1.96 = 0.06.$

Appendix Table 10.—Daily gain (corrected for feed)*

Lot and Station Averages—1937 and 1938

Station	Barley 3 C.W. Feed 1937	Barley 1 C.W. Feed 1938	Barley 2 C.W. Feed 1938	Barley 3 C.W. Feed 1938	Barley Oats 1937	Barley Oats 1938	Oats 1937	Corn 1937	Corn 1938	Corn Oats 1937	Station averages
A	1.50	1.59	1.52	1.44	1.44	1.47	1.29	1.45	1.35	1.41	1.45
B	1.51	1.47	1.55	1.47	1.45	1.51	1.32	1.42	1.30	1.46	1.45
C	1.45	1.58	1.60	1.55	1.38	1.53	1.35	1.47	1.45	1.39	1.48
D	1.46	1.63	1.60	1.58	1.38	1.57	1.31	1.41	1.44	1.49	1.44
E	1.38	1.44	1.42	1.39	1.29	1.34	1.25	1.38	1.31	1.33	1.35
Lot averages	1.46	1.54	1.54	1.49	1.39	1.48	1.30	1.43	1.37	1.42	1.44

Standard deviation of adjusted gains* = 0.1175 lbs.

Necessary difference between lot means* = 0.08 lbs.

* For statistical procedures used in adjusting gains for feed intake, for obtaining standard deviations of the adjusted gains, and the necessary difference between lot means, see page 371.

Appendix Table 11.—Carcass score

Lot and Station Averages—1937 and 1938

Station	Barley 3 C.W. Feed 1937	Barley 1 C.W. Feed 1938	Barley 2 C.W. Feed 1938	Barley 3 C.W. Feed 1938	Barley Oats 1937	Barley Oats 1938	Oats 1937	Corn 1937	Corn 1938	Corn Oats 1937	Station averages
A	74	84	81	72	79	71	78	68	58	75	74.1
B	78	76	84	74	75	72	71	75	58	72	73.6
C	63	84	83	75	60	77	68	54	69	66	69.9
D	82	82	79	76	83	71	79	76	67	82	77.7
E	79	73	72	80	71	72	61	66	62	68	70.5
Lot averages	75.2	79.9	79.9	75.4	73.6	72.8	71.4	67.9	62.9	72.8	73.2

Analysis of Variance

Description	D/F	$S(x-\bar{x})^2$	σ^2	σ	F values		$C.V.$
					Observed	Necessary	%
Total	249	30174.16					
Between sub-classes	49	13838.96					
Between lots	9	5923.92	658.21		7.78	1.92	
Between stations	4	1979.42	494.86		5.84	2.41	
Interaction	36	5935.62	164.88		1.95	1.45	
Calculated values	7						
Remainder	193	16335.20	84.64	9.20			12.57

Necessary difference between lot means $= \frac{9.20}{\sqrt{25}} \times \sqrt{2} \times 1.96 = 5.10.$

Necessary difference between station means $= \frac{9.20}{\sqrt{50}} \times \sqrt{2} \times 1.96 = 3.61.$

Appendix Table 12.—Cold carcass weight

Lot and Station Averages—1937 and 1938

Station	Barley 3 C.W. Feed 1937	Barley 1 C.W. Feed 1938	Barley 2 C.W. Feed 1938	Barley 3 C.W. Feed 1938	Barley Oats 1937	Barley Oats 1938	Oats 1937	Corn 1937	Corn 1938	Corn Oats 1937	Station averages
A	154	158	150	150	148	156	148	158	156	148	152.7
B	154	149	149	146	154	151	143	158	159	156	151.9
C	154	158	155	156	147	149	149	159	154	153	153.5
D	147	150	150	152	142	148	143	158	149	146	148.5
E	151	151	150	153	143	153	142	155	148	149	149.6
Lot averages	152.0	153.2	150.7	151.4	147.0	151.3	145.0	157.8	153.4	150.4	151.2

Analysis of Variance

Description	D/F	$S(x - \bar{x})^2$	σ^2	σ	F values		$C.V.$
					Observed	Necessary	%
Total	249	18820.90					
Between sub-classes	49	5469.70					
Between lots	9	2754.42	306.04		4.47	1.92	
Between stations	4	893.64	223.41		3.26	2.41	
Interaction	36	1821.64	50.60		—	—	
Calculated values	5						
Remainder	195	13351.20	68.47	8.27			5.47

Necessary difference between lot means $= \frac{8.27}{\sqrt{25}} \times \sqrt{2} \times 1.96 = 4.59.$

Necessary difference between station means $= \frac{8.27}{\sqrt{50}} \times \sqrt{2} \times 1.96 = 3.24.$

Appendix Table 13.—Carcass length

Lot and Station Averages—1937 and 1938

Station	Barley 3 C.W. Feed 1937	Barley 1 C.W. Feed 1938	Barley 2 C.W. Feed 1938	Barley 3 C.W. Feed 1938	Barley Oats 1937	Barley Oats 1938	Oats 1937	Corn 1937	Corn 1938	Corn Oats 1937	Station averages
A	31.0	30.9	30.2	30.1	30.4	30.4	30.5	29.8	29.4	30.4	30.4
B	29.8	30.1	29.9	29.8	31.0	30.7	31.0	30.3	29.5	30.7	30.2
C	30.1	30.6	31.2	30.1	29.7	30.6	30.8	29.7	30.2	30.6	30.3
D	29.9	30.2	31.0	31.5	30.2	29.9	30.0	30.3	29.7	29.9	30.3
E	30.5	31.0	30.5	31.3	30.4	31.2	30.1	30.8	30.5	31.2	30.7
Lot averages	30.3	30.6	30.6	30.6	30.3	30.5	30.5	30.2	29.9	30.6	30.4

Analysis of Variance

Description	D/F	$S(x - \bar{x})^2$	σ^2	σ	F values		$C.V.$
					Observed	Necessary	%
Total	249	196.90					
Between sub-classes	49	60.80					
Between lots	9	11.05	1.23		1.76	1.92	
Between stations	4	5.66	1.41		2.03	2.41	
Interaction	36	44.09	1.22		1.75	1.45	
Calculated values	5						
Remainder	195	136.11	.70	.84			2.75

Necessary difference between lot means $= \frac{0.84}{\sqrt{25}} \times \sqrt{2} \times 1.96 = 0.46.$

Necessary difference between station means $= \frac{0.84}{\sqrt{50}} \times \sqrt{2} \times 1.96 = 0.33.$

Appendix Table 14.—Percentage shoulders

Lot and Station Averages—1937 and 1938

Station	Barley 3 C.W. Feed 1937	Barley 1 C.W. Feed 1938	Barley 2 C.W. Feed 1938	Barley 3 C.W. Feed 1938	Barley Oats 1937	Barley Oats 1938	Oats 1937	Corn 1937	Corn 1938	Corn Oats 1937	Station averages
A	29.3	29.3	28.9	29.2	29.1	29.8	30.4	29.0	28.2	29.7	29.3
B	28.8	28.4	27.8	28.9	30.5	29.8	30.5	28.7	29.8	29.3	29.2
C	28.3	27.6	26.9	28.7	30.5	28.2	29.8	28.3	28.5	29.7	28.7
D	28.1	27.9	28.7	27.7	28.1	28.0	28.6	27.5	27.8	27.7	28.0
E	28.0	28.1	28.3	28.1	29.2	27.3	29.8	28.6	27.8	28.7	28.4
Lot averages	28.5	28.2	28.1	28.5	29.5	28.6	29.8	28.4	28.4	29.0	28.7

Analysis of Variance

Description	D/F	$S(x - \bar{x})^2$	σ^2	σ	F values		$C.V.$
					Observed	Necessary	%
Total	249	429.80					
Between sub-classes	49	195.68					
Between lots	9	69.40	7.71		6.42	1.92	
Between stations	4	60.75	15.19		12.65	2.41	
Interaction	36	65.53	1.82		1.52	1.45	
Calculated values	5						
Remainder	195	234.11	1.20	1.10			3.82

Necessary difference between lot means $= \frac{1.10}{\sqrt{25}} \times \sqrt{2} \times 1.96 = 0.61.$

Necessary difference between station means $= \frac{1.10}{\sqrt{50}} \times \sqrt{2} \times 1.96 = 0.43.$

Appendix Table 15.—Percentage middles

Lot and Station Averages—1937 and 1938

Station	Barley 3 C.W. Feed 1937	Barley 1 C.W. Feed 1938	Barley 2 C.W. Feed 1938	Barley 3 C.W. Feed 1938	Barley Oats 1937	Barley Oats 1938	Oats 1937	Corn 1937	Corn 1938	Corn Oats 1937	Station averages
A	45.8	46.9	46.9	46.2	46.0	44.9	44.0	47.4	49.2	46.0	46.3
B	47.4	47.1	48.4	45.8	45.0	45.6	44.2	47.0	46.9	46.9	46.4
C	47.6	49.1	50.5	48.0	46.2	48.8	46.5	48.2	48.6	47.1	48.1
D	47.7	47.7	47.1	48.1	47.1	48.2	46.9	48.6	48.9	48.2	47.8
E	47.4	47.6	47.4	47.9	45.9	48.2	45.7	47.6	48.6	47.3	47.4
Lot averages	47.2	47.7	48.1	47.2	46.0	47.2	45.4	47.8	48.4	47.1	47.2

Analysis of Variance

Description	D/F	$S(x - \bar{x})^2$	σ^2	σ	F values		$C.V.$
					Observed	Necessary	%
Total	249	851.08					
Between sub-classes	49	420.82					
Between lots	9	180.93	20.10		9.11	1.92	
Between stations	4	127.35	31.84		14.43	2.41	
Interaction	36	112.53	3.13		1.42	1.45	
Calculated values	5						
Remainder	195	430.27	2.21	1.49			3.15

Necessary difference between lot means $= \frac{1.49}{\sqrt{25}} \times \sqrt{2} \times 1.96 = 0.82.$

Necessary difference between station means $= \frac{1.49}{\sqrt{50}} \times \sqrt{2} \times 1.96 = 0.58.$

Appendix Table 16.—Percentage hams

Lot and Station Averages—1937 and 1938

Station	Barley 3 C.W. Feed 1937	Barley 1 C.W. Feed 1938	Barley 2 C.W. Feed 1938	Barley 3 C.W. Feed 1938	Barley Oats 1937	Barley Oats 1938	Oats 1937	Corn 1937	Corn 1938	Corn Oats 1937	Station averages
A	24.9	23.8	24.2	24.5	24.9	25.3	25.6	23.7	22.6	24.3	24.4
B	23.8	24.5	23.8	25.3	24.6	24.6	25.2	24.3	23.3	23.8	24.3
C	24.1	23.3	22.6	23.3	23.2	22.9	23.8	23.5	23.0	23.1	23.3
D	24.2	24.4	24.3	24.2	24.8	23.8	24.5	23.9	23.4	24.1	24.2
E	24.6	24.3	24.3	24.0	24.9	24.5	24.6	23.8	23.6	24.0	24.3
Lot averages	24.3	24.0	23.8	24.3	24.5	24.2	24.7	23.8	23.2	23.9	24.1

Analysis of Variance

Description	D/F	$S(x - \bar{x})^2$	σ^2	σ	F values		$C.V.$
					Observed	Necessary	%
Total	249	260.88					
Between sub-classes	49	117.56					
Between lots	9	42.51	4.72		6.43	1.92	
Between stations	4	41.76	10.44		14.20	2.41	
Interaction	36	33.29	.92		1.26	1.45	
Calculated values	5						
Remainder	195	143.32	.73	.86			3.56

Necessary difference between lot means $= \frac{0.86}{\sqrt{25}} \times \sqrt{2} \times 1.96 = 0.48.$

Necessary difference between station means $= \frac{0.86}{\sqrt{50}} \times \sqrt{2} \times 1.96 = 0.34.$

Appendix Table 17.—Shoulder fat

Lot and Station Averages—1937 and 1938

Station	Barley 3 C.W. Feed 1937	Barley 1 C.W. Feed 1938	Barley 2 C.W. Feed 1938	Barley 3 C.W. Feed 1938	Barley Oats 1937	Barley Oats 1938	Oats 1937	Corn 1937	Corn 1938	Corn Oats 1937	Station averages
A	1.7	1.8	1.8	1.8	1.8	1.7	1.6	2.0	2.1	1.8	1.81
B	1.9	1.7	1.7	1.7	1.7	1.7	1.6	1.9	2.1	1.8	1.79
C	1.9	2.0	1.9	2.0	2.1	1.9	1.9	2.2	2.0	2.0	2.00
D	2.0	1.9	2.1	2.1	1.9	2.0	1.9	2.2	2.2	2.0	2.03
E	1.8	1.7	1.9	1.7	1.5	1.8	1.7	2.1	1.9	1.8	1.79
Lot averages	1.87	1.83	1.87	1.87	1.79	1.84	1.74	2.07	2.08	1.88	1.88

Analysis of Variance

Description	D/F	$S(x - \bar{x})^2$	σ^2	σ	F values		$C.V.$
					Observed	Necessary	%
Total	249	15.93					
Between sub-classes	49	7.26					
Between lots	9	2.65	.29		6.62	1.92	
Between stations	4	2.96	.74		16.64	2.41	
Interaction	36	1.65	.05		1.03	1.45	
Calculated values	5						
Remainder	195	8.67	.04	.21			11.19

Necessary difference between lot means $= \frac{0.21}{\sqrt{25}} \times \sqrt{2} \times 1.96 = 0.12.$

Necessary difference between station means $= \frac{0.21}{\sqrt{50}} \times \sqrt{2} \times 1.96 = 0.08.$

Appendix Table 18.—Back fat

Lot and Station Averages—1937 and 1938

Station	Barley 3 C.W. Feed 1937	Barley 1 C.W. Feed 1938	Barley 2 C.W. Feed 1938	Barley 3 C.W. Feed 1938	Barley Oats 1937	Barley Oats 1938	Oats 1937	Corn 1937	Corn 1938	Corn Oats 1937	Station averages
A	.9	1.1	1.2	1.1	1.1	1.0	.9	1.2	1.5	1.0	1.10
B	1.3	1.0	1.0	1.0	.9	.9	.8	1.2	1.2	1.1	1.05
C	1.1	1.3	1.1	1.1	.9	1.0	.9	1.3	.9	1.0	1.07
D	1.2	1.3	1.3	1.2	1.1	1.2	1.1	1.5	1.2	1.2	1.22
E	1.0	1.0	1.1	1.0	.9	1.0	.8	1.1	1.1	1.0	1.01
Lot averages	1.11	1.13	1.13	1.07	.98	1.03	.89	1.28	1.20	1.05	1.09

Analysis of Variance

Description	D/F	$S(x - \bar{x})^2$	σ^2	σ	F values		$C.V.$
					Observed	Necessary	%
Total	249	12.28					
Between sub-classes	49	6.08					
Between lots	9	2.70	.30		9.44	1.92	
Between stations	4	1.36	.34		10.73	2.41	
Interaction	36	2.01	.06		1.76	1.45	
Calculated values	5						
Remainder	195	6.20	.03	.18			16.38

Necessary difference between lot means $= \frac{0.18}{\sqrt{25}} \times \sqrt{2} \times 1.96 = 0.10.$

Necessary difference between station means $= \frac{0.18}{\sqrt{50}} \times \sqrt{2} \times 1.96 = 0.07.$

Appendix Table 19.—Loin fat

Lot and Station Averages—1937 and 1938

Station	Barley 3 C.W. Feed 1937	Barley 1 C.W. Feed 1938	Barley 2 C.W. Feed 1938	Barley 3 C.W. Feed 1938	Barley Oats 1937	Barley Oats 1938	Oats 1937	Corn 1937	Corn 1938	Corn Oats 1937	Station averages
A	1.3	1.5	1.5	1.4	1.4	1.4	1.2	1.7	2.0	1.4	1.47
B	1.7	1.5	1.3	1.3	1.3	1.3	1.2	1.7	1.6	1.4	1.43
C	1.4	1.5	1.4	1.5	1.2	1.4	1.3	1.7	1.5	1.4	1.44
D	1.5	1.5	1.5	1.5	1.4	1.4	1.3	1.8	1.5	1.5	1.49
E	1.2	1.3	1.4	1.2	1.1	1.4	1.1	1.5	1.5	1.2	1.28
Lot averages	1.43	1.46	1.43	1.38	1.29	1.36	1.22	1.66	1.62	1.37	1.42

Analysis of Variance

Description	D/F	$S(x - \bar{x})^2$	σ^2	σ	F values		$C.V.$
					Observed	Necessary	%
Total	249	13.91					
Between sub-classes	49	7.32					
Between lots	9	4.07	.45		13.39	1.92	
Between stations	4	1.40	.35		10.36	2.41	
Interaction	36	1.85	.05		1.52	1.45	
Calculated values	5						
Remainder	195	6.59	.03	.18			12.93

Necessary difference between lot means $= \frac{0.18}{\sqrt{25}} \times \sqrt{2} \times 1.96 = 0.10.$

Necessary difference between station means $= \frac{0.18}{\sqrt{50}} \times \sqrt{2} \times 1.96 = 0.07.$

Appendix Table 20.—Fat evenness

Lot and Station Averages—1937 and 1938

Station	Barley 3 C.W. Feed 1937	Barley 1 C.W. Feed 1938	Barley 2 C.W. Feed 1938	Barley 3 C.W. Feed 1938	Barley Oats 1937	Barley Oats 1938	Oats 1937	Corn 1937	Corn 1938	Corn Oats 1937	Station averages
A	.7	.7	.6	.8	.7	.7	.7	.7	.6	.8	.71
B	.6	.7	.6	.7	.8	.8	.8	.7	.9	.8	.75
C	.8	.7	.9	.9	1.1	.9	1.0	.9	1.0	1.0	.93
D	.8	.7	.8	.9	.8	.8	.8	.7	1.0	.8	.81
E	.8	.6	.8	.7	.6	.8	.9	.9	.8	.8	.77
Lot averages	.76	.68	.74	.80	.81	.81	.85	.79	.87	.84	.79

Analysis of Variance

Description	D/F	$S(x - \bar{x})^2$	σ^2	σ	F values		$C.V.$
					Observed	Necessary	%
Total	249	10.39					
Between sub-classes	49	3.36					
Between lots	9	.71	.08		2.20	1.92	
Between stations	4	1.46	.36		10.11	2.41	
Interaction	36	1.19	.03		—	—	
Calculated values	5						
Remainder	195	7.03	.04	.19			23.89

Necessary difference between lot means $= \frac{0.19}{\sqrt{25}} \times \sqrt{2} \times 1.96 = 0.10.$

Necessary difference between station means $= \frac{0.19}{\sqrt{50}} \times \sqrt{2} \times 1.96 = 0.07.$

Appendix Table 21.—Maximum belly thickness

Lot and Station Averages—1937 and 1938

Station	Barley 3 C.W. Feed 1937	Barley 1 C.W. Feed 1938	Barley 2 C.W. Feed 1938	Barley 3 C.W. Feed 1938	Barley Oats 1937	Barley Oats 1938	Oats 1937	Corn 1937	Corn 1938	Corn Oats 1937	Station averages
A	1.3	1.7	1.4	1.5	1.5	1.4	1.4	1.4	1.6	1.4	1.46
B	1.4	1.6	1.4	1.4	1.4	1.4	1.2	1.6	1.6	1.4	1.44
C	1.7	1.7	2.0	1.6	1.8	1.7	1.5	2.0	1.8	1.7	1.77
D	1.8	1.6	1.6	1.6	1.6	1.7	1.5	1.8	1.9	1.6	1.67
E	1.7	1.6	1.6	1.5	1.6	1.6	1.3	1.8	1.6	1.6	1.59
Lot averages	1.61	1.64	1.58	1.52	1.56	1.55	1.40	1.74	1.71	1.56	1.59

Analysis of Variance

Description	D/F	$S(x - \bar{x})^2$	σ^2	σ	F values		$C.V.$
					Observed	Necessary	%
Total	249	15.42					
Between sub-classes	49	7.53					
Between lots	9	2.03	.23		5.59	1.92	
Between stations	4	3.78	.95		23.38	2.41	
Interaction	36	1.71	.05		1.18	1.45	
Calculated values	5						
Remainder	195	7.89	.04	.20			12.68

Necessary difference between lot means $= \frac{0.20}{\sqrt{25}} \times \sqrt{2} \times 1.96 = 0.11.$

Necessary difference between station means $= \frac{0.20}{\sqrt{50}} \times \sqrt{2} \times 1.96 = 0.08.$

APPENDIX TABLE 22.—MINIMUM BELLY THICKNESS

Lot and Station Averages—1937 and 1938

Station	Barley 3 C.W. Feed 1937	Barley 1 C.W. Feed 1938	Barley 2 C.W. Feed 1938	Barley 3 C.W. Feed 1938	Barley Oats 1937	Barley Oats 1938	Oats 1937	Corn 1937	Corn 1938	Corn Oats 1937	Station averages
A	.7	1.0	.7	.9	.7	.7	.7	.8	.9	.7	.78
B	.8	.9	.7	.8	.7	.8	.6	.8	1.0	.7	.78
C	.7	.9	.9	.9	.7	.8	.6	.9	.9	.7	.81
D	1.0	.9	1.0	1.0	1.0	.9	.9	1.0	1.0	1.0	.99
E	.6	.6	.6	.6	.5	.6	.5	.7	.6	.6	.59
Lot averages	.77	.84	.80	.81	.72	.78	.69	.83	.91	.75	.79

Analysis of Variance

Description	D/F	$S(x - \bar{x})^2$	σ^2	σ	F values		$C.V.$
					Observed	Necessary	%
Total	249	9.79					
Between sub-classes	49	5.78					
Between lots	9	.90	.10		4.86	1.92	
Between stations	4	4.03	1.01		48.85	2.41	
Interaction	36	.84	.02		1.14	1.45	
Calculated values	5						
Remainder	195	4.02	.02	.14			18.17

Necessary difference between lot means $= \frac{0.14}{\sqrt{25}} \times \sqrt{2} \times 1.96 = 0.08.$

Necessary difference between station means $= \frac{0.14}{\sqrt{50}} \times \sqrt{2} \times 1.96 = 0.06.$

APPENDIX TABLE 23.—AREA OF LOIN MUSCLE

Lot and Station Averages—1937 and 1938

Station	Barley 3 C.W. Feed 1937	Barley 1 C.W. Feed 1938	Barley 2 C.W. Feed 1938	Barley 3 C.W. Feed 1938	Barley Oats 1937	Barley Oats 1938	Oats 1937	Corn 1937	Corn 1938	Corn Oats 1937	Station averages
A	7.0	5.5	6.1	5.9	6.5	6.4	6.5	6.3	4.3	6.2	6.06
B	6.6	5.5	5.8	6.2	6.6	6.1	6.5	6.1	5.2	6.1	6.08
C	5.1	6.4	6.0	6.6	4.8	6.4	5.1	4.5	5.0	4.7	5.47
D	6.1	5.6	5.3	5.3	6.4	5.3	5.5	5.7	4.6	5.6	5.53
E	4.8	4.1	4.2	4.7	4.4	4.2	4.5	4.4	3.6	4.3	4.31
Lot averages	5.92	5.42	5.46	5.74	5.75	5.68	5.62	5.39	4.54	5.37	5.49

Analysis of Variance

Description	D/F	$S(x - \bar{x})^2$	σ^2	σ	F values		$C.V.$
					Observed	Necessary	%
Total	249	297.32					
Between sub-classes	49	181.86					
Between lots	9	32.55	3.62		6.08	1.92	
Between stations	4	103.35	25.84		43.41	2.41	
Interaction	36	45.97	1.28		2.15	1.45	
Calculated values	6						
Remainder	194	115.46	.59	.77			14.06

Necessary difference between lot means $= \frac{0.77}{\sqrt{25}} \times \sqrt{2} \times 1.96 = 0.43.$

Necessary difference between station means $= \frac{0.77}{\sqrt{50}} \times \sqrt{2} \times 1.96 = 0.30.$

APPENDIX TABLE 24.—PERCENTAGE LEAN IN TOTAL RASHER*

Lot Averages—1937 and 1938

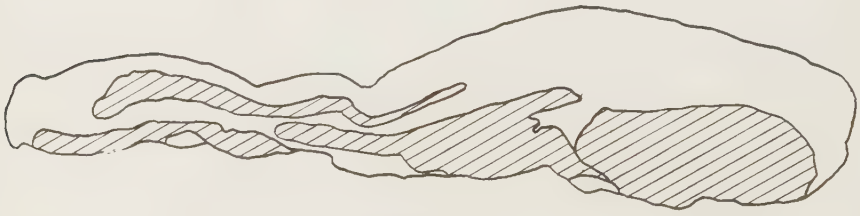
Station	Barley 3 C.W. Feed 1937	Barley 1 C.W. Feed 1938	Barley 2 C.W. Feed 1938	Barley 3 C.W. Feed 1938	Barley Oats 1937	Barley Oats 1938	Oats 1937	Corn 1937	Corn 1938	Corn Oats 1937	Station averages
Lot averages	44.01	41.08	41.21	44.34	46.41	45.18	48.02	39.13	31.07	39.91	—

Analysis of Variance

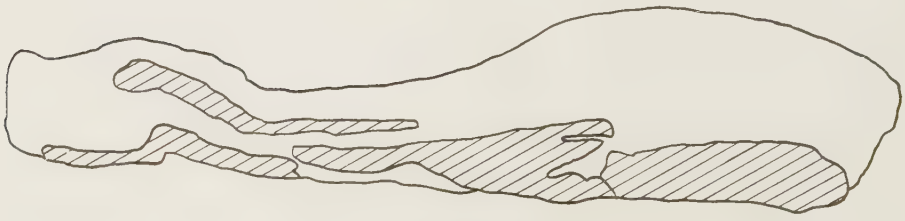
Description	D/F	$S(x - \bar{x})^2$	σ^2	σ	F values		$C.V.$
					Observed	Necessary	%
Total	99	3925.47					
Between lots	9	2088.44	232.05		10.99	1.99	
Calculated values	3						
Remainder	87	1837.03	21.11	4.59			10.93

Necessary difference between lot means $= \frac{4.59}{\sqrt{10}} \times \sqrt{2} \times 1.96 = 4.03.$

* 100 hogs from Macdonald College tests only.



Barley fed.



Corn fed.

FIGURE 1. Typical bacon rasher patterns projected from tracings of actual cross section cuts of carcass from barley fed (Lot I) and corn fed (Lot IV) hogs.

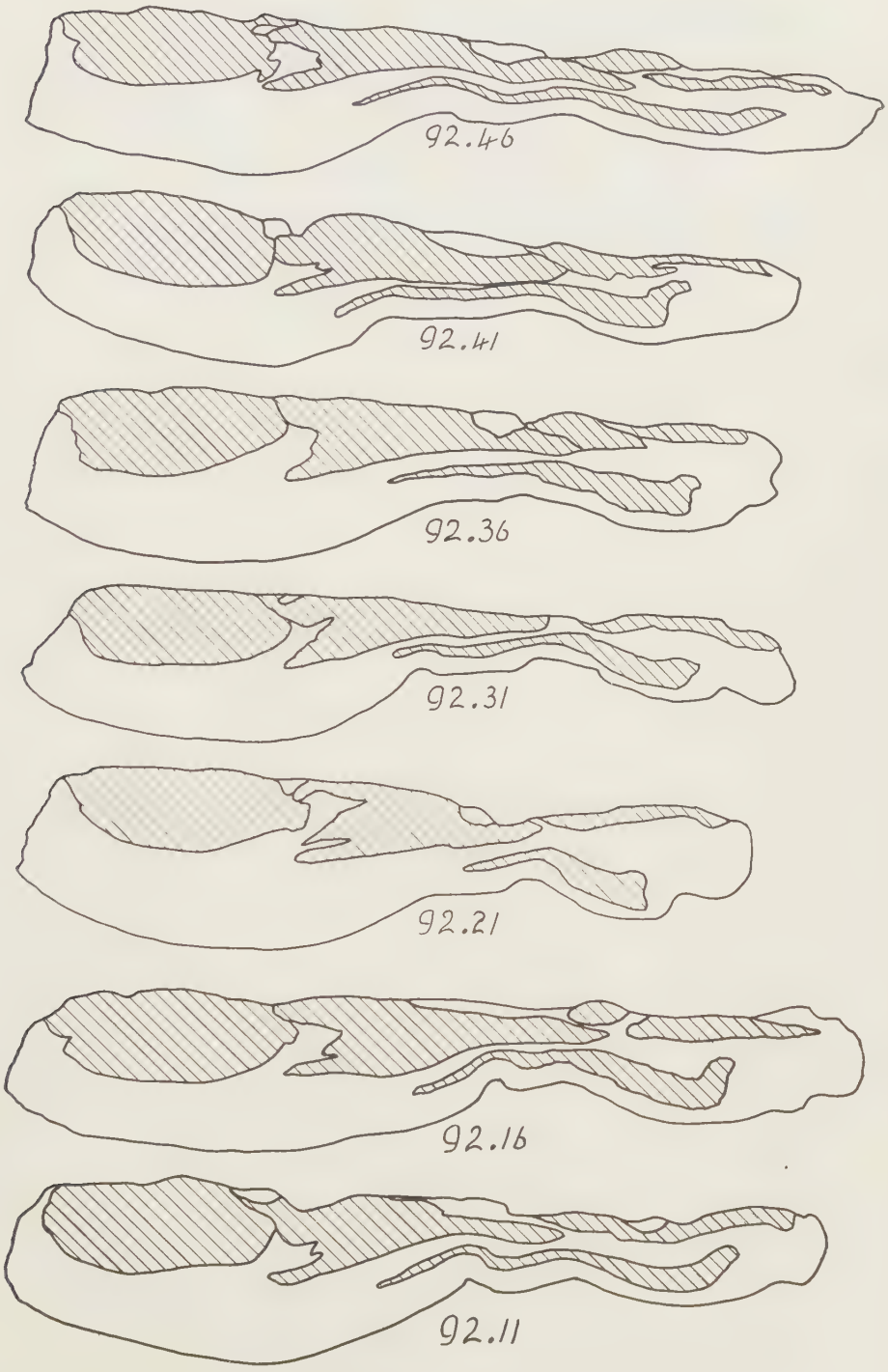


FIGURE 2.

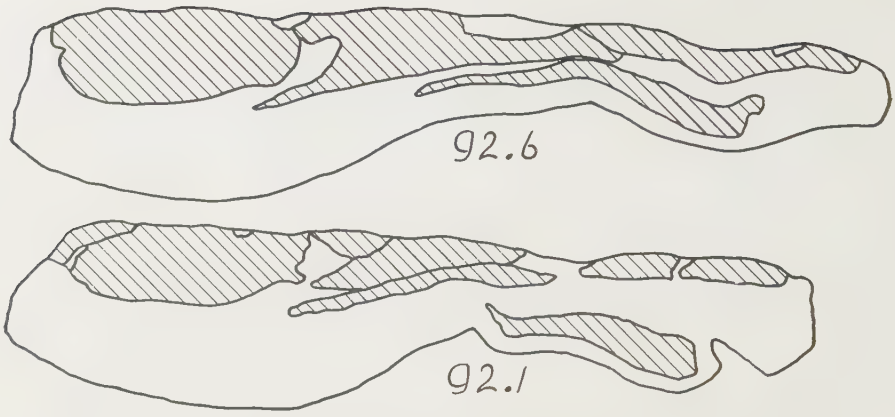


FIGURE 2. Bacon rasher pattern from pigs fed basal ration of No. 1 Feed Barley (1938 tests at Macdonald College).

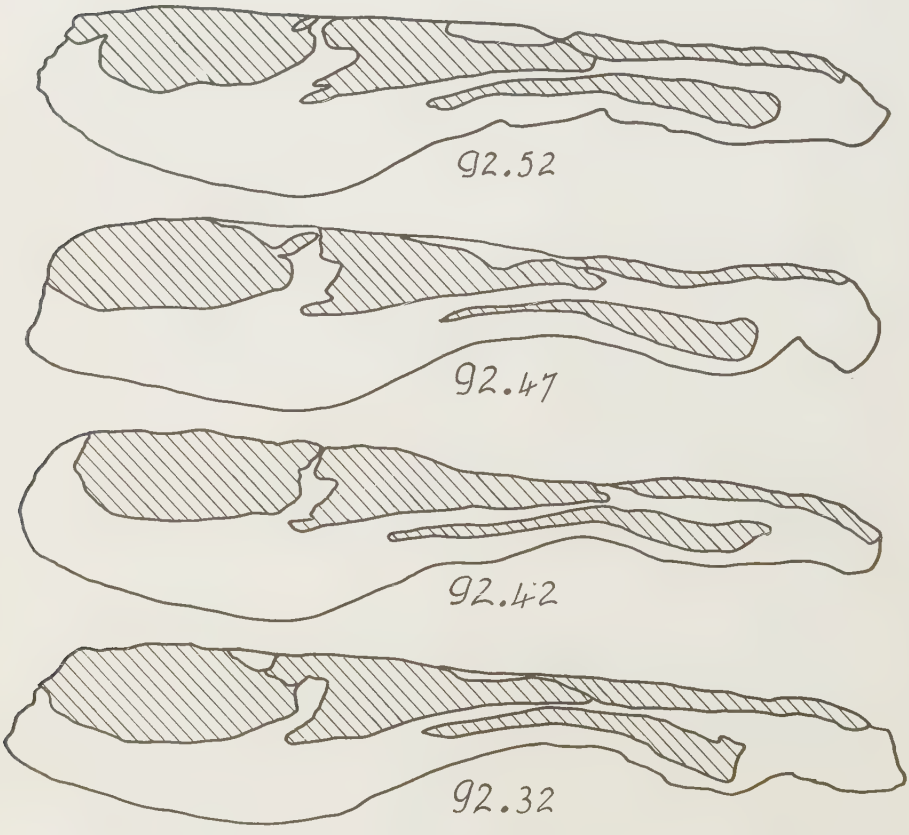


FIGURE 3.

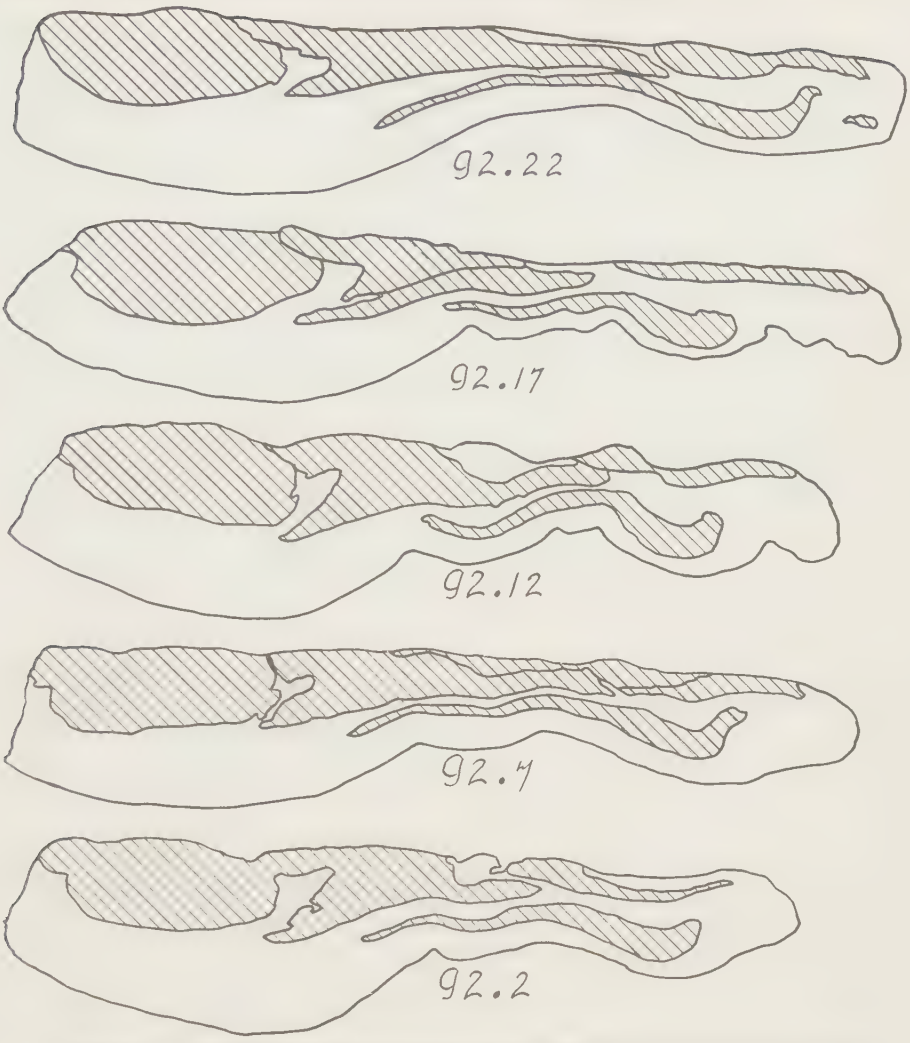


FIGURE 3. Bacon rasher pattern from pigs fed basal ration of No. 2 Feed barley (1938 tests at Macdonald College).

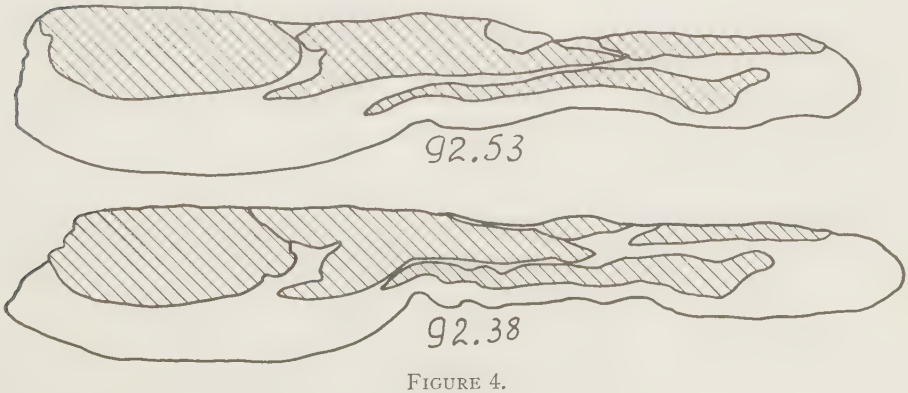


FIGURE 4.

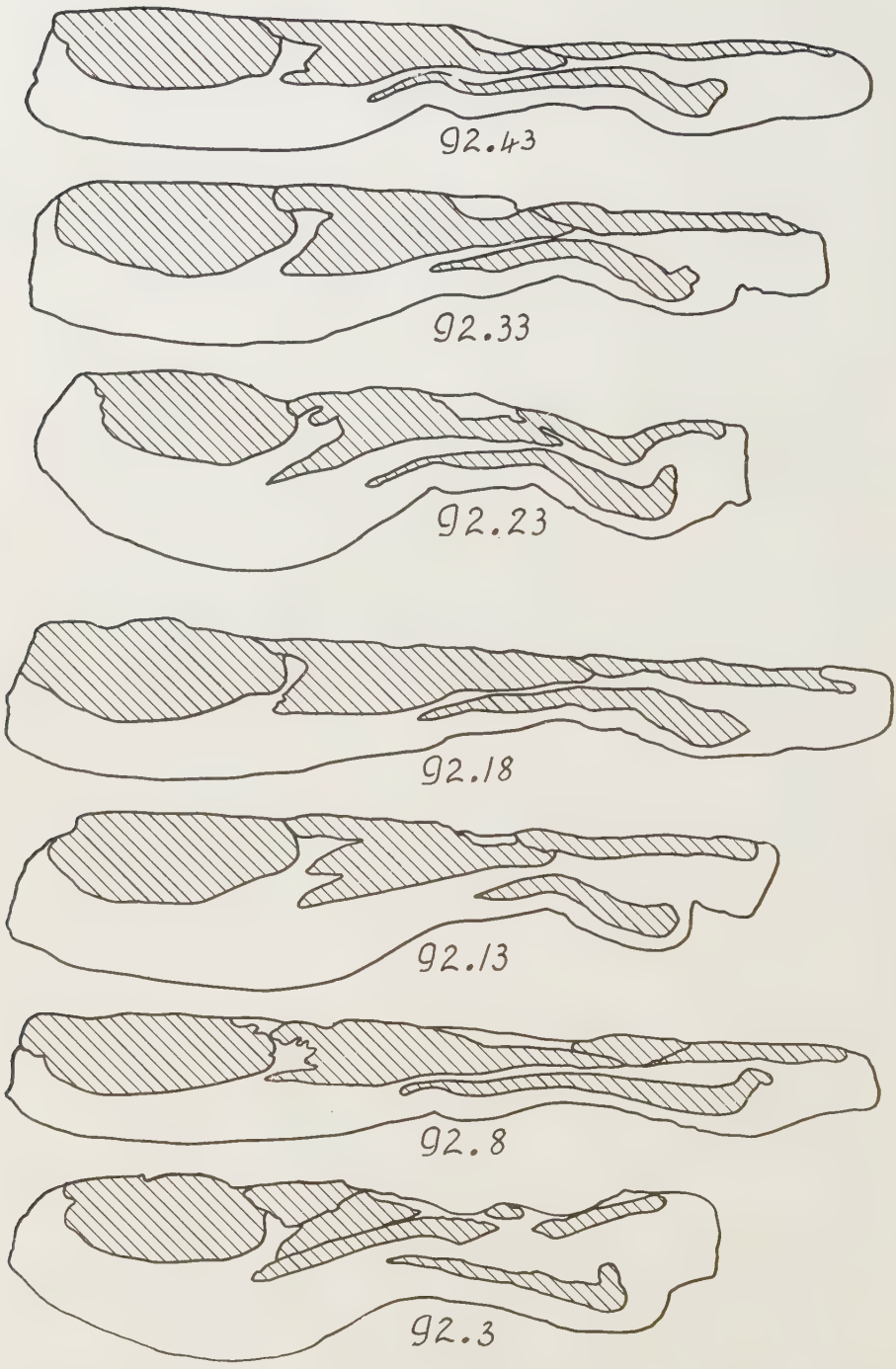


FIGURE 4. Bacon rasher pattern from pigs fed basal ration of No. 3 Feed barley (1938 tests at Macdonald College).

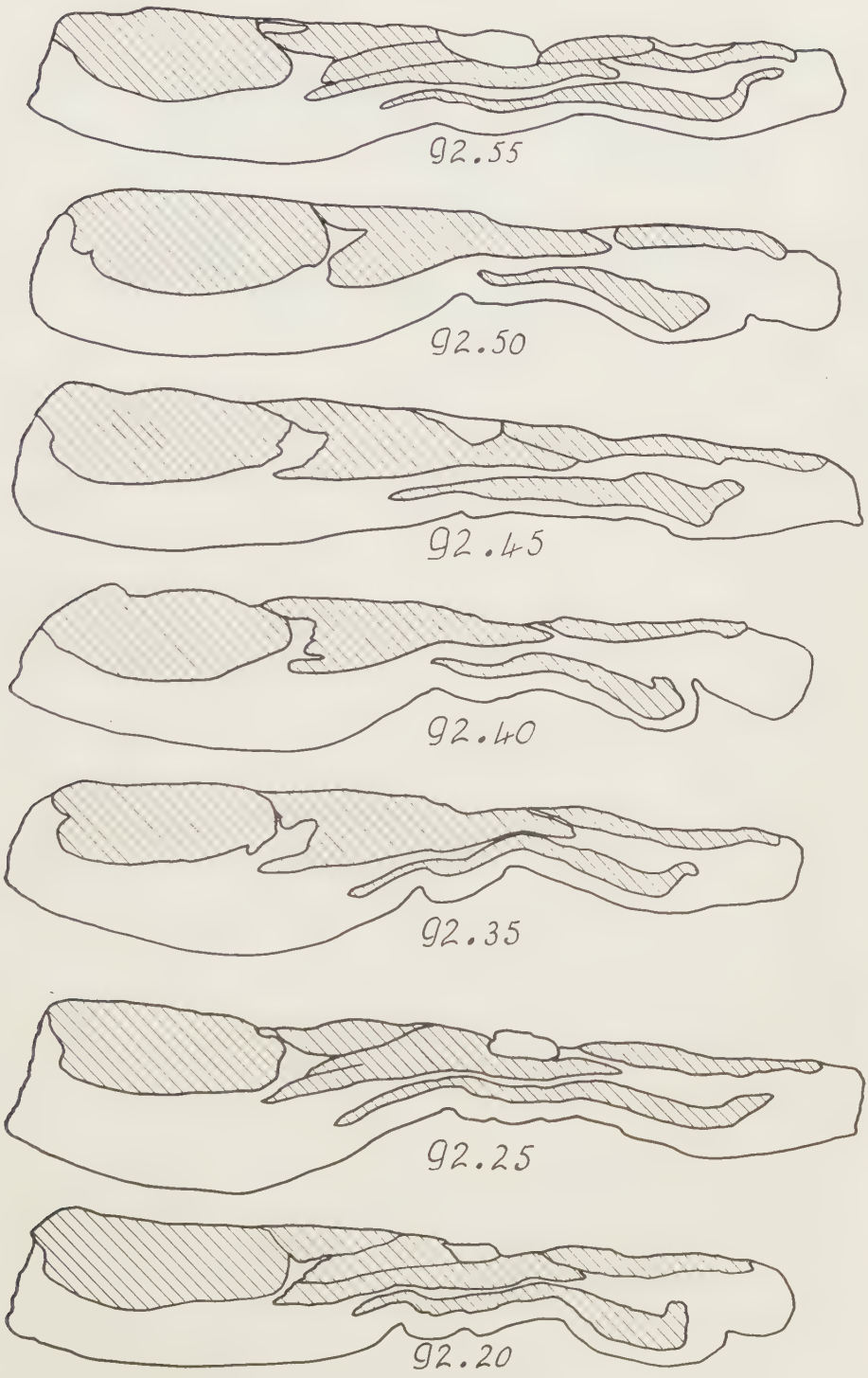


FIGURE 5.

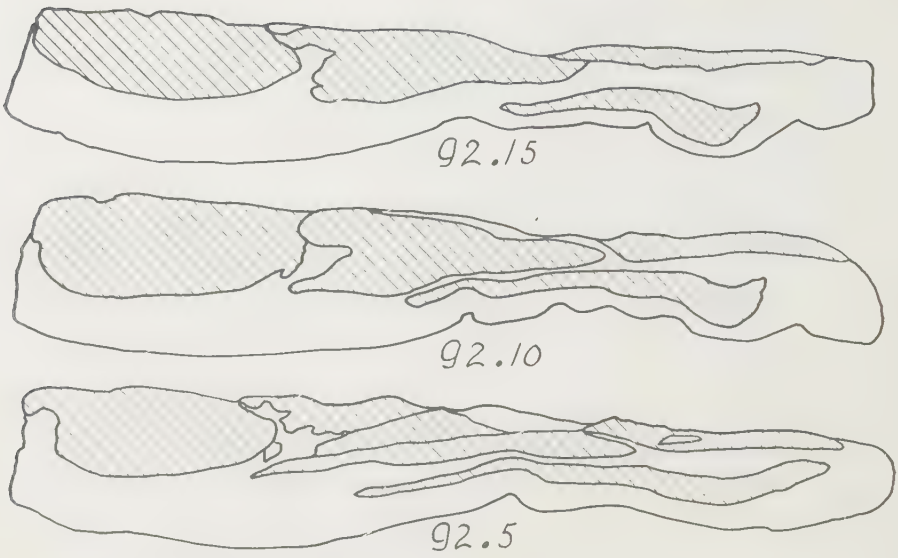


FIGURE 5. Bacon rasher pattern from pigs fed basal ration of No. 1 Feed barley 50% + No. 3 C. W. oats 50% (1938 tests at Macdonald College).

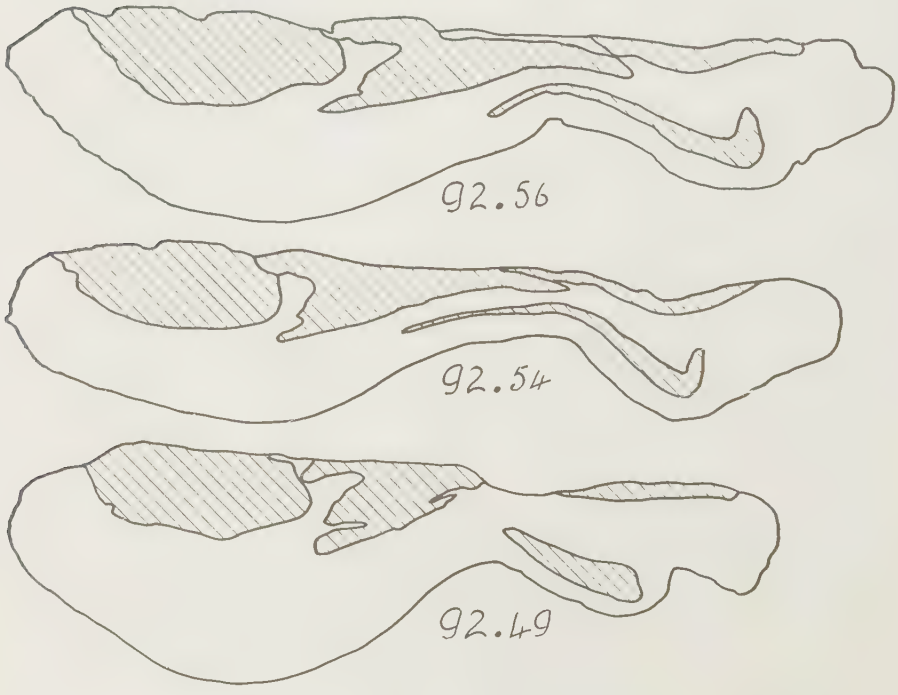


FIGURE 6.

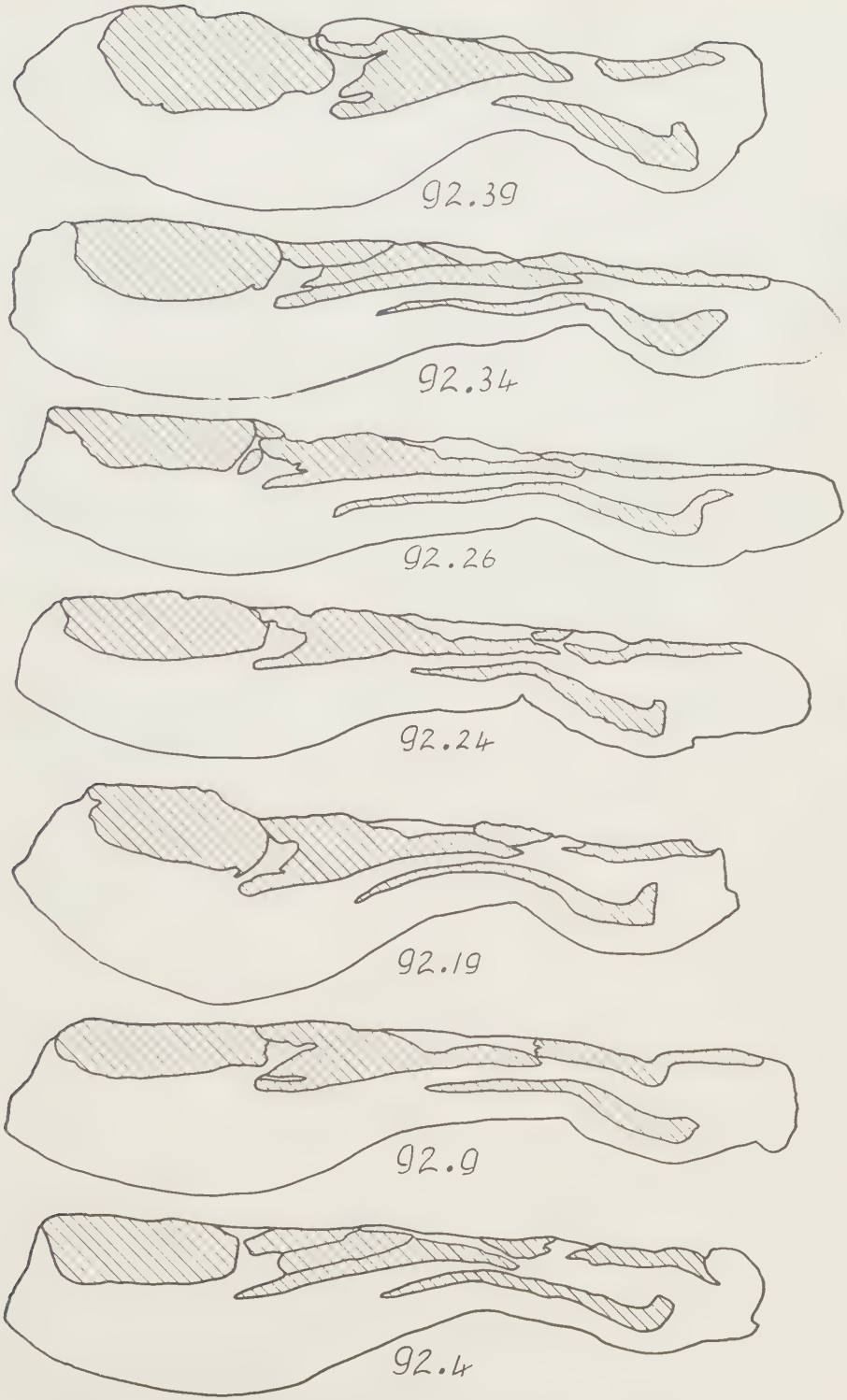


FIGURE 6. Bacon rasher pattern from pigs fed basal ration of yellow corn (1938 tests at Macdonald College).

THE BREEDING SIGNIFICANCE OF AFTER-HARVEST SPROUTING IN WHEAT[1]

J. B. HARRINGTON[2] AND P. F. KNOWLES[3]
University of Saskatchewan, Saskatoon, Sask.

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Most of the wheat growing regions of the world appear to be faced with the possibility of moist weather occurring at harvest time. If the moist weather is prolonged or accompanied by moderately high temperatures, sprouting of the standing or stocked grain may occur. Even a small proportion of sprouted grain results in a lowering of market quality and if the sprouting is severe the crop may be completely unmarketable.

Generally speaking, sprouting has not been a serious menace to Western Canadian agriculture, but in the northern parts of the farming area where fall rains are more frequent, it has resulted in large losses, particularly in the variety Garnet. Losses from sprouting in the central and southern districts would probably have been much greater if the variety Marquis, with its high sprouting resistance, had not occupied the major portion of the wheat acreage. Now that new disease resistant varieties are being originated at the different breeding institutions the question arises: Is not resistance to sprouting a character which deserves a place in the list of those to which special attention should be directed by the breeder?

It is well known that wheat varieties differ in their tendency to germinate immediately after maturity. In 1932 Harrington (4) reported results from after-harvest sprouting studies conducted at Saskatoon, Saskatchewan in 1927 and 1931. He found in the 14 varieties studied a range from Garnet, which sprouted very readily, to Marquis which showed a marked resistance to sprouting. Deming and Robertson (2) found in a Colorado study a range from Marquis, which showed high resistance to sprouting, to Federation which sprouted readily as soon as mature. Scholz (6) studied 149 varieties of Czechoslovakian and other wheats and found large differences in after-ripening, some varieties germinating as soon as ripe and others not for many weeks.

From September 6 to 11, 1938, moist warm weather, especially conducive to the sprouting of grain, prevailed at Saskatoon, Saskatchewan. Slight rains occurred intermittently throughout the period but the heaviest precipitation was on September 9 and 10 when 2.16 inches of rain fell. During the 6 days the total precipitation was 2.42 inches and the average temperature was 61.4° F. The relative humidity averaged 81.7% as compared with 51.5% for the preceding 6 days.

At the time of this wet period, border rows of most of the wheat breeding plots were still standing although the centre rows had been harvested for yield determinations from 17 to 45 days previously. The border rows were examined after the rains and distinct differences were noted between different varieties and hybrid lines with respect to sprouting in the spike. This was not only true of material which had recently matured but also of varieties and hybrids which had matured 40 to 45 days before

[1] Contribution from the Field Husbandry Department, University of Saskatchewan, Saskatoon, Canada.
[2] Professor of Field Husbandry.
[3] Graduate Assistant in Plant Breeding.

the rain. Many of the hybrid lines belonged to a project for breeding early maturing wheat for Northern Saskatchewan. Since resistance to sprouting is highly desirable in Western Canada, a study was made of the comparative reactions of hybrid lines from several crosses.

PROCEDURE

Data on sprouting were taken from a number of nurseries as follows: *(a)* Six heads were taken at random from each of the 6 replicates of each variety in the co-operative test of rust resistant wheat varieties. This test matured 40 to 45 days before the rains and comprised promising varieties from Canadian and United States breeding institutions. *(b)* One replicate of each variety in preliminary hybrid wheat variety tests XI, XII, XIII, XVI, and XVII was sampled. Each sample consisted of about 15 heads, half of which were collected at one end of the plot, and half from the other end. The date of maturity in these tests was 35 to 45 days before the wet weather occurred. *(c)* A late-sown root-rot test included hybrid lines that could not be obtained in the preliminary yield tests, owing to these tests having been completely harvested before the rain. Random samples of about 15 heads each were taken from the border rows. In contrast to the previously mentioned material, this test matured 15 to 20 days before the wet weather. *(d)* Under ordinary conditions wheat is threshed in less than 45 days of the time it ripens; consequently it was fortunate that most of hybrid lines in the preliminary yield tests were also present in a special straw strength nursery, known as test XXV, which was late-sown and matured 17 to 24 days before the rain. From test XXV samples of all the material that was mentioned above as being in the preliminary yield tests or in the root-rot tests were taken. The rows in this test were 8 feet long and each sample consisted of the heads in the centre 6 feet of row.

Sprouting percentage was determined from threshed grain, 100 kernels being taken at random in each replicate of the co-operative test, and duplicate 100-kernel samples in the other tests. A kernel was called sprouted if the bran was broken in the region of the embryo. In some cases, the sprouts were one-eighth inch long, but most of the sprouting consisted only of a small split in the bran.

Statistical analysis was limited to the results from the co-operative test and to the Marquis checks in Test XXV. The co-operative test was laid out according to Yates (7) incomplete randomized block method. Before variance analysis was applied to the data, they were scrutinized to determine whether they conformed to a normal frequency distribution. The distribution was found to be decidedly skewed. However, variance analysis can be applied to such data, providing it is transformed to convert the skewness into the semblance of a normal distribution. Cochran (1), in a recent paper, points out that the square root transformation as modified by Bartlett is satisfactory for data of this kind. The modified transformation consists of taking the square root of each variate after adding 0.5 to it. Usually the inverse sine transformation is used on percentage data, but, according to Cochran, where the percentages are below 70, as in the present case excepting for one variety, the square root transformation is even more satisfactory to use.

As data forming a skew distribution are frequently encountered in agronomic investigations, and as the point has not been discussed in Canadian agronomic literature, the writers have thought it worth while to show both the original and the transformed results in full. These are given in Tables 1 and 2. Owing to the layout of the experiment being according to Yates modified block plan all of the transformed data had to be corrected to furnish valid means to use for the different varieties. Each of the corrected means then had to be reconverted by squaring and subtracting 0.5 in order to restore the original order of magnitude.

In other studies, data were taken from Test XXV and from either the root-rot or the preliminary yield tests. In this way, data from two sources were used in the comparison of the varieties and hybrid lines. Marquis was used throughout as a standard for comparison. Marquis occurred as a check in the preliminary yield tests and the root-rot test. In test XXV Marquis was included as a running check, and each hybrid was compared with the 2 nearest Marquis rows. The 45 Marquis checks ranged from 3 to 30% sprouting with 10 in the 1 to 10% class, 27 in the 11 to 20% class and 8 in the 21 to 30% class. The mean sprouting percentage was 15.2 ± 1.4.

TABLE 1.—GERMINATION PERCENTAGES OF VARIETIES AND SELECTIONS IN THE CO-OPERATIVE TEST OF RUST-RESISTANT WHEATS AT SASKATOON, 1938

Sask. No.	Can. Acc. No.	Variety or hybrid	Replicates						Mean
			1	2	3	4	5	6	
2087	1907	Ceres × Reward	2	3	1	3	4	8	3.5
1703	1857	Apex	1	0	0	9	8	13	5.2
2086	1905	Ma. × (H44 × Ma.)	2	7	3	0	2	25	6.5
2088	1908	Reward × Marquillo	2	4	2	6	3	1	3.0
1789	1909	Apex	1	0	2	2	10	15	5.0
2081	1880	Hope × Reward	2	16	1	3	17	3	7.0
2082	1916	Hope × Reward	1	2	13	5	7	15	7.2
2076	1935	Ma. × (H44 × Ma.)	2	8	4	14	7	13	8.0
1720	1820	Thatcher	1	1	8	9	9	12	6.7
1735	1856	Renown	4	3	2	6	15	17	6.8
2077	1936	H44 × Reward	32	6	11	3	8	6	11.0
100	1404	Marquis	5	18	7	8	31	14	13.8
1920	1915	Renown	7	15	14	12	19	27	15.7
1744	1878	Hope & Reward	19	18	5	8	48	17	19.2
1739	1873	H44 × Reward	27	6	21	30	36	35	25.8
1912	1902	Regent	16	17	23	22	30	29	22.8
2078	1937	Ma. × (H44 × Ma.)	52	24	5	41	38	23	30.5
1212	1263	Ceres	31	6	29	34	25	65	31.7
2084	1910	Ceres × Hope	34	36	21	21	22	43	29.8
1910	1934	Rival	25	38	45	6	39	48	33.5
2085	1912	Ceres × (Hope × Fl.)	39	27	28	61	52	48	42.5
1741	1874	H44 × Reward	45	41	30	24	65	33	39.7
2079	1938	H44 × Reward	40	45	21	38	47	25	36.0
1003	1509	Reward	42	65	45	20	50	42	44.0
791	1316	Garnet	94	86	85	95	91	89	90.0
		Average							21.8

NOTE.—Hybrids Sask. 2087, 2088, 2082 and 2081 were originated at the Dominion Experimental Farm, Brandon, Manitoba; Hybrids Sask. 2086, 2076, 2077, 1739, 1744, 2078, 2079, and 1741 were bred at the Dominion Rust Research Laboratory, Winnipeg, Manitoba; Hybrid Sask. 2085 was produced by the North Dakota Agricultural College, Fargo; Hybrid Sask. 2084 was bred by the United States Department of Agriculture.

Abbreviations: Ma—Marquis; Fl—Florence; H44—H44-24; Can—Canadian.

RESULTS

Table 2 shows the results from the co-operative test of rust-resistant wheats. The varieties and selections have been listed in order of resistance to sprouting. They vary from a selection of a Ceres × Reward cross, with a sprouting percentage of 2.9, to the variety Garnet with an average sprouting percentage of 89.9. The 3 stem-rust-resistant varieties Apex, Renown and Thatcher, which are now in wide use in Western Canada,

TABLE 2.—DATA OF TABLE 1 TRANSFORMED BY THE SQUARE ROOT METHOD WITH A VARIANCE ANALYSIS OF THESE SQUARE ROOTS ACCORDING TO YATE'S INCOMPLETE RANDOMIZED BLOCK PLAN

Can. Acc. No.	Variety or hybrid	Replicates 1	2	3	4	5	6	Mean	Cor. mean +	Recon. mean Θ	Resist. rating ≠
1907	Ceres × Reward	1.58	1.87	1.22	1.87	2.12	2.92	1.93	1.84	2.9	V R
1857	Apex	1.22	.71	.71	3.08	2.92	3.67	2.05	1.87	3.0	V R
1905	Ma. × (H44 × Ma.)	1.58	2.74	1.87	.71	1.58	5.05	2.26	1.93	3.2	V R
1908	Reward × Marquillo	1.58	2.12	1.58	2.55	1.87	1.22	1.82	1.98	3.4	V R
1909	Apex	1.22	.71	1.58	1.58	3.24	3.94	2.04	2.27	4.6	V R
1880	Hope × Reward	1.58	4.06	1.22	1.87	4.18	1.87	2.46	2.48	5.6	V R
1916	Hope × Reward	1.22	1.58	3.67	2.34	2.74	3.94	2.58	2.52	5.8	V R
1935	Ma. × (H44 × Ma.)	1.58	2.92	2.12	3.81	2.74	3.67	2.81	2.64	6.5	V R
1820	Thatcher	1.22	1.22	2.92	3.08	3.08	3.54	2.51	2.72	6.9†	V R
1856	Renown	2.12	1.87	1.58	2.55	3.94	4.18	2.71	2.86	7.7	V R
1936	H44 × Reward	5.70	2.55	3.39	1.87	2.92	2.55	3.16	3.20	9.7	V R
1404	Marquis	2.34	4.30	2.74	2.92	5.61	3.81	3.62	3.49	11.7	R
1915	Renown	2.74	3.94	3.81	3.54	4.42	5.24	3.95	4.05	15.9†	R
1878	Hope × Reward	4.42	4.30	2.34	2.92	6.96	4.18	4.19	4.41	19.0	R
1873	H44 × Reward	5.24	2.55	4.64	5.52	6.04	5.96	4.99	4.57	20.4	R
1902	Regent	4.06	4.18	4.85	4.74	5.52	5.43	4.80	4.81	22.6	M R
1937	Ma. × (H44 × Ma.)	7.24	4.95	2.34	6.44	6.20	4.85	5.34	5.20	26.5	M R
1263	Ceres	5.61	2.55	5.43	5.87	5.05	8.09	5.43	5.66	31.5	M R
1910	Ceres × Hope	5.87	6.04	4.64	4.64	4.74	6.60	5.42	5.70	32.0	M R
1934	Rival	5.05	6.20	6.74	2.55	6.28	6.96	5.63	5.86	33.8	M S
1912	Ceres × (Hope × *Fl*)	6.28	5.24	5.34	7.84	7.24	6.96	6.48	6.10	36.7	M S
1874	H44 × Reward	6.74	6.44	5.52	4.95	8.09	5.79	6.26	6.12	27.0	M S
1938	H44 × Reward	6.36	6.74	4.64	6.20	6.89	5.05	5.98	6.22	38.2†	M S
1509	Reward	6.52	8.09	6.74	4.53	7.11	6.52	6.58	6.51	41.9†	M S
1316	Garnet	9.72	9.30	9.25	9.77	9.56	9.46	9.51	9.51	89.9	V S

+ Due to the use of Yate's method of randomization it was necessary to calculate corrected variety means (7).

≠ In each table the results are classified roughly for resistance and each hybrid is given a resistance rating on the basis of the known behaviour of the parental varieties, as follows: VR 1% to 11% sprouting; R = 12% to 22%; MR = 23% to 33%; MS = 34% to 51%; S = 52% to 69%; VS = 70% to 100%. R = resistant, S = susceptible, V = very, M = moderately.

Θ The corrected means reconverted by squaring so as to restore their original order of magnitude.

† The bars indicate in each case that the variety immediately below had significantly more sprouting than the variety immediately below the next higher bar.

VARIANCE ANALYSIS

Source of error	Sum of squares	Degrees of freedom	Mean square	*F* value	5% point	1% point
Blocks	155.720	29	5.370	2.78	1.63	1.98
Varieties	384.007	24	16.000	8.29	1.63	1.98
Error	185.287	96	1.930			
Total	725.014	149				

S.D. = 1.52 $\quad S E_v = \sqrt{\frac{1.93 \times 30}{6}} = 0.62 = 14.9\%.$

TABLE 3.—SPROUTING RESULTS FROM THE CROSSES GARNET × REWARD, REWARD × RELIANCE, REWARD × MARQUIS AND REWARD × CERES

Variety or Line	Test XXV		Rootrot test		Average	
	Sprouting, %	Approx. resistance rating	Sprouting, %	Approx. resistance rating	Sprouting, %	Approx. resistance rating
Garnet	81	VS	96	VS	88	VS
Reward	11	VR	23	MR	17	R
Marquis	15	R	23	MR	19	R
Reliance	41	MS	42	MS	41	MS
Ceres	53	S	81	VS	69	S
GrRw–119	97	VS	94	VS	95	VS
" 121	47	MS	59	S	53	S
" 123	2	VR	1	VR	1*	VR
" 124	38	MS	50	MS	44	MS
" 133	73	VS	64	S	69	S
RwRl–51	22	R	40	MS	31	MR
" 52	14	R	9	VR	11	VR
" 54	5	VR	11	VR	8	VR
" 55	11	VR	29	MR	20	MR
" 56	37	MS	51	MS	44	MS
" 59	10	VR	7	VR	8	VR
" 61	33	MR	33	MR	33	MR
" 63	24	MR	34	MS	29	MR
" 64	5	VR	26	MR	15	R
" 67	27	MR	28	MR	27	MR
" 68	21	R	50	MS	35	MS
" 74	20	R	40	MS	30	MR
" 75	20	R	30	MR	25	MR
" 76	4	VR	17	R	10	VR
" 77	16	R	41	MS	28	MR
" 79	31	MR	25	MR	28	MR
" 84	11	VR	20	R	15	R
" 90	31	MR	61	S	46	MS
" 93	46	MS	29	MR	37	MS
RwMa–138	4	VR	8	VR	6	VR
" 140	3	VR	10	VR	6	VR
" 141	4	VR	14	R	9	VR
" 143	8	VR	23	MR	15	R
" 146	20	R	24	MR	22	R
" 151	11	VR	29	MR	20	R
" 152	6	VR	12	R	9	VR
" 153	1	VR	2	VR	1*	VR
" 154	2	VR	3	VR	2	VR
" 157	4	VR	22	R	13	R
" 161	4	VR	22	R	13	R
" 163	10	VR	12	R	11	VR
RwCe–222	26	MR	82	VS	54	S
" 224	29	MR	72	VS	50	MS
" 226	19	MR	79	VS	49	MS
" 228	42	MS	68	S	55	S
" 231	20	R	76	VS	48	MS
" 233	50	MS	81	VS	65	S
" 234	26	MR	18	R	22	R
" 235	58	S	42	MS	50	MS
" 236	52	S	82	VS	67	S
" 239	38	MS	53	S	45	MS
" 240	9	VR	42	MS	25	MR

Abbreviations: GrRw = Garnet × Reward line III–36–; RwRl = Reward × Reliance line III–36–; RwMa = Reward × Marquis line III–36–; RwCe = Reward × Ceres III–37–; R = Resistant; S = Susceptible; M = Moderate, V = Very.

* Correct although appears to be incorrect due to all results being expressed in nearest whole numbers.

showed high resistance to sprouting and were significantly better in that respect than the 2 newer rust resistant varieties, Regent and Rival. None of the unnamed new varieties had higher percentages of sprouting than Reward but, compared with Marquis, 7 showed less sprouting and 7 showed more.

Results on the crosses Garnet × Reward, Reward × Reliance, Reward × Marquis and Reward × Ceres are presented in Table 3. The data on each line were obtained from Test XXV as well as from the root-rot test. As maturity in both tests occurred from 20 to 14 days before the wet weather, the results are closely comparable.

In the cross Garnet × Reward the high sprouting susceptibility of Garnet and the moderate resistance of Reward afforded a wide scope for progeny behaviour. The lines exceeded the range of the parental varieties. One line, No. 123, showed an average of only 1.2% of sprouting as compared with 16.5% for Reward. The other 4 lines were all more or less susceptible.

TABLE 4.—SPROUTING RESULTS FROM THE CROSS (REWARD × GARNET) F_1 × A 41–3

Variety or Line	Test XXV		Test XI		Average	
	Sprouting, %	Approx. resistance rating	Sprouting, %	Approx. resistance rating	Sprouting, %	Approx. resistance rating
Garnet	81	VS	59	S	70	VS
Reward	11	R	51	MS	31	MR
Marquis	15	R	17	R	16	R
A 41	8	VR				
RG41–1	84	VS	56	S	70	VS
" 6	73	VS	65	VS	69	VS
" 7	3	VR	17	R	10	VR
" 14	17	R	10	R	13	VR
" 15	13	R	46	MS	29	MR
" 21	27	MR	53	S	40	MS
" 22	11	VR	35	MS	23	MR
" 25	17	R	34	MS	25	MR
" 26	12	R	69	S	40	MS
" 27	62	S	80	VS	71	VS
" 28	16	R	24	MR	20	R
" 30	7	VR	42	MS	24	MR
" 31	41	MS	26	MR	33	MS
" 32	57	S	55	S	56	S
" 33	38	MS	48	MS	43	MS
" 34	8	VR	15	R	11*	VR
" 36	73	VS	45	MS	59	S
" 37	85	VS	69	S	77	VS
" 38	76	VS	53	S	65	VS
" 39	28	MR	36	MS	32	MR
" 41	20	R	46	S	33	MR
" 44	2	VR	8	VR	5	VR
" 45	28	MR	54	S	41	MS
" 46	34	MS	50	MS	42	MS
" 50	12	R	53	S	32	MR
" 51	32	MR	58	S	45	S
" 52	28	MR	70	VS	41	S
" 53	4	VR	30	MR	17	R

*See footnote of Table 3.

The 2 sets of results for the Reward × Reliance cross are not quite as consistent as those of Garnet × Reward. However, with 2 exceptions, the same hybrids ranked high in resistance in both tests. Four lines appeared to be more resistant than Reward. Of the 19 lines only 4 were moderately susceptible like Reliance; all the rest could be classified as resistant. The range of variation among the hybrids was, as might be anticipated, not as large as in the case of the Garnet × Reward lines.

The cross Reward × Marquis is of interest because both parents are resistant. It is of particular interest that half of the lines showed more resistance to sprouting than either parent. None of the lines showed susceptibility or even a low degree of resistance.

In contrast to these results are those from the cross Reward × Ceres. Ceres is more susceptible than Reliance but distinctly less susceptible than Garnet. Two lines sprouted as little as Reward and 2 as much as Ceres; the others were intermediate.

TABLE 5.—SPROUTING RESULTS FROM THE CROSSES GARNET × A277–2, (REWARD × GARNET)F_1 × A130–1, AND (REWARD × GARNET)F_1 × A269–1

Variety or Line	Test XXV		Test XII		Average	
	Sprouting, %	Approx. resistance rating	Sprouting, %	Approx. resistance rating	Sprouting, %	Approx. resistance rating
Garnet	81	VS	75	VS	78	VS
Reward	11	R	51	MS	31	MR
Marquis	15	R	7	VE	11	VR
A 277	0	VR				
A 130	4	VR				
A 269	1	VR				
G277–96	68	S	67	S	68	S
" 98	57	S	50	MS	53	S
" 99	91	VS	80	VS	85	VS
" 110	11	VR	7	VR	9	VR
" 111	70	VS	44	MS	57	S
" 113	44	MS	16	R	30	MR
" 115	58	S	46	S	52	S
" 116	53	S	43	S	48	S
" 118	93	VS	79	VS	86	VS
" 119	50	S	31	MR	41	MS
" 121	75	VS	42	MS	58	S
" 123	48	S	30	MR	39	MS
" 124	33	MR	42	MS	38	MS
RG130–129	8	VR	8	VR	8	VR
" 131	39	MS	48	MS	43	MS
" 132	60	S	68	S	64	S
" 136	5	VR	4	VR	5	VR
" 140	53	S	28	MR	41	MS
RG269–247	37	MS	53	S	45	MS
" 248	61	S	62	S	61*	S
"						

Abbreviations: G277 = Garnet × A277–2, III–37–; Rg130 = (Reward × Garnet) F_1 × A130–1, III–37–; RG269 = (Reward × Garnet)F_1 × A269–1, III–37–.

* See footnote of table 3.

Table 4 contains 2 sets of results on the cross (Reward × Garnet) × A41 – 3. The variety A41 – 3 is a stem rust resistant sib of Apex. One set of results is from Test XXV, which matured late, and the other from Test XI which matures 3 weeks earlier. The two sets of data differ considerably, many lines showing much more sprouting in Test XI than in Test XXV. This difference is exactly what would be expected on the basis of the dormancy studies made by the writers (5) in 1937 and 1938. Twelve hybrid lines were as resistant to sprouting as Marquis in Test XXV, but in Test XI only 4 of these equalled Marquis. Apparently some lines maintained for several weeks after maturity a sprouting resistance equal to that of Marquis but subsequently lost the resistance more rapidly than did Marquis. The sprouting percentages of the hybrids covered the entire range of the parental varieties.

Table 5 gives results on the crosses Garnet × A277 – 2, (Reward × Garnet) F_1 × A130 – 1 and (Reward × Garnet) F_1 × A269 – 1. The rust-resistant parents in each case were highly resistant to sprouting. In the cross Garnet × A277 – 2 only one line, No. 110, was highly resistant to sprouting. The others ranged from MR to VS. In several cases lines showed less sprouting in Test XII than in Test XXV although the former ripened several weeks earlier than Test XXV. This same tendency is suggested in the results on Garnet. However this is a minor point compared with the contrast between lines that sprout easily and those which resist sprouting. In the cross (Reward × Garnet)F_1 × A130 – 1 there was a larger proportion of resistant lines than in Garnet × A277 – 2, apparently due to the dilution of Garnet inheritance. In all these crosses it is noticeable that selection on the basis of the usual agronomic and seed characters failed to eliminate the lines with undesirable sprouting propensities. Among the 20 lines only 4 are satisfactorily resistant to sprouting. Of the remaining 16 lines 10 are classed as S or VS.

A summarization of the line distributions of the crosses shown in Tables 3, 4, and 5 is presented in Table 6. In addition, this table includes a summary on 3 other crosses A277 – 2 × Reliance, Quality × Ceres and (Quality × Ceres) F_1 × Ceres. The last 2 were added to show results from crosses involving no resistant varieties. These 2 crosses produced no VR or R lines but most of the lines sprouted less than the parental varieties. Out of the total of 144 lines 51 are classified as being as low as or lower than Marquis in percentage of sprouting and 34 lines sprouted as much as or more than Ceres. Only 5 lines were as susceptible to sprouting as Garnet.

A close examination of Table 6 reveals the fact that the distribution of the lines for sprouting depends upon the sprouting characteristics of the parents. The more resistant the parents, the more resistant are the progeny lines. The range of reaction may be traced through the crosses from Reward × Marquis, a cross of two resistant varieties, to Quality × Ceres, a cross of 2 susceptible varieties.

Data on the standard varieties was available from several tests other than those discussed. A summarization of all the results on these varieties is of interest and appears in Table 7. There was a considerable amount of fluctuation in the performance of individual varieties but in some cases this could be attributed to dormancy differences due to length of time elapsed

TABLE 6.—SUMMARIZATION OF THE COMPARATIVE SPROUTING PERCENTAGES OF HYBRID LINES AND PARENTS OF 11 CROSSES

Variety or line	Distribution of hybrid lines and varieties according to the percentage of sprouting										
	0 to 4	5 to 9	10 to 19	20 to 29	30 to 39	40 to 49	50 to 59	60 to 69	70 to 79	80 to 89	90 to 99
Rw × Rl		2	4	6	5	2					
Parents			Rw			Rl					
Gr × Rw	1					1	1	1			1
Parents			Rw							Gr	
Rw × Ma	2	4	4	2							
Parents			Rw Ma								
Rw × Ce				2		3	4	2			
Parents			Rw					Ce			
Rw–Gr × 41*	3	2	7	5	3	1	1	1	3	2	
Parents		41	Rw							Gr	
Gr × 277*			1		1	2	4	1	2		2
Parents	277									Gr	
Rw–Gr × 130*		2			1		1	1			
Parents	130		Rw							Gr	
Rw–Gr × 269*					1			1			
Parents	269		Rw							Gr	
277 × Rl±	3	5	11	10	2	2	2				
Parents	277							Rl			
Qu × Ce*				2	2	1	1	1			
Qu–Ce × Ce*				1		4	1	1			
Parents							Qu Ce				
Total for lines	9	15	27	28	15	16	15	9	5	2	3

Abbreviations: Rw = Reward, Rl = Reliance, Gr = Garnet, Ma = Marquis, Ce = Ceres, 41 = A41–3, 277 = A277–2, 130 = A130–1, 269 = A269–1, Qu = Quality.

* Considering data from the late maturing test only. ± From test XVI only.

NOTE: Results on 277 × Rl, Qu × Ce and Qu–Ce × Ce are not shown in other tables.

TABLE 7.—COMPARISON OF STANDARD VARIETIES FOR PERCENTAGE OF SPROUTING

Variety	Tests that matured approximately six weeks before the rains						Tests that matured three weeks before the rains		Means for all tests excepting R. Rot
	XI	XII	XIII	XVI	XVII	Co-op.	R. Rot	XXV	
Marquis	17.0	7.0	3.5	11.0	12.0	11.7	23.0	15.2	11.0
Garnet	58.5	75.0	92.0	79.0	76.5	89.9	96.0	80.5	78.8
Thatcher	4.0	8.0	12.5	8.5	3.5	6.9		2.5	6.5
Apex	2.5	1.5	8.5	2.0	8.0	3.8	1.0	1.5	3.9
Reward	51.0				44.0	41.9	22.5	10.5	
Renown						11.8		5.0	
Reliance				61.0			41.5	41.0	
Ceres			66.5			31.5	80.5	53.0	

between maturity of the wheat and the occurrence of the rains. The writers (5) have shown that a variety may lose much of its dormancy during a period of several weeks after maturity. Reward germinated about like Marquis in the late tests but more than 3 times as much as Marquis in the early tests. Reliance also germinated more in the early tests than in the late ones. Marquis was more consistent in its performance. Apex and Thatcher were very consistent throughout. Each of these 3 varieties maintained its degree of sprouting resistance throughout the 6 weeks period. Summarizing, the order of resistance to sprouting in these tests beginning with the most resistant was, Apex 1789, Thatcher, Renown, Marquis, Reward, Reliance, Ceres, and Garnet.

DISCUSSION

Sprouting Resistance, a Manifestation of Dormancy

The failure of most of the seeds of a variety to germinate when they are exposed to moist weather for several days may be due to slow germination or it may be due to the possession of an after-ripening or dormancy period. The authors', in a recent paper (5) showed marked differences in dormancy between varieties of wheat. The dormancy results agree well with the sprouting results in this paper for varieties which appeared in both tests, *viz.*

High resistance to sprouting	Apex, Thatcher, Renown
Long dormancy period	Apex, Renown
Medium resistance to sprouting	Marquis, Reward
Medium dormancy period	Marquis, Reward, Thatcher
Low resistance to sprouting	Reliance
Short dormancy period	Reliance
Very low resistance to sprouting	Garnet
Very short dormancy period	Garnet

This agreement suggests that the differences in sprouting results were due to differences in dormancy and not to differences in rapidity of germination.

Other evidence in support of considering the differences in resistance to sprouting as being manifestations of dormancy is available in a comparison of the results of Table 7 with those of the dormancy study referred to. In that paper it was shown that in 1938 Apex 1789, and to lesser extents Reward and Reliance, retained some dormancy for 10 weeks after maturity but that Garnet had almost completely lost its dormancy within 4 weeks after maturity. In the sprouting tests early sown nurseries and late sown nurseries were used. The former ripened about 6 weeks prior to the rains and the latter, comprising Test XXV and the root-rot nursery, matured approximately 3 weeks before the wet spell. The average sprouting percentages for the 4 varieties in the 2 sets of nurseries are as follows:

	Late maturing	Early maturing
	%	%
Apex 1789	1	4
Reward	17	46
Reliance	41	61
Garnet	88	79

The results are just what would be expected on the basis of dormancy. It seems clear that the differences observed in the sprouting data may be attributed legitimately to differences in dormancy.

Concerning the Accuracy of the Data

The data used in this study were obtained as a result of a very favourable opportunity to ascertain the comparative resistance to sprouting of wheat varieties and hybrids. It is not feasible to make special sowing of hundreds of hybrid lines for sprouting tests because the occurrence of suitably unfavourable harvest weather is unpredictable both as to time and effect. It is however highly desirable to have field sprouting data to relate to laboratory dormancy data as a check on the practical usefulness of the latter for determining the comparative merits of different hybrids.

The accuracy of the sprouting data may be judged from Table 3 where results from 2 nurseries which ripened at approximately the same time are, with few exceptions, highly consistent. Nevertheless a proportion of the variation in the results shown in Table 3 may be attributed to errors of sampling, for the data from systematic Marquis checks occurring every fifth row throughout Test XXV showed a standard error of 7% for a duplicate sample comparable to the samples representing the hybrids. However, on the whole sampling errors do not account for an important part of the differences. The consistency of the data is also shown in the varietal summarization of Table 7.

The results of Tables 4 and 5 appear to indicate considerable variation. However, much of this is explained by the fact that Test XXV ripened only 3 weeks before the rains whereas the other tests were ripe 3 weeks earlier. These results proved of special value in revealing the lines which showed very little sprouting in Text XXV and a much larger amount in the preliminary yield tests, or in other words appeared to have the Reward type of dormancy.

Breeding Considerations

Perhaps the most striking thing about these results is the presence in several crosses of hybrid lines which displayed more sprouting resistance than the resistant parental variety. The best example is Garnet × Reward III – 36 – 123 with an average of 1.2% of sprouting compared with 88.2% for Garnet and 16.5% for Reward. It appears evident that transgressive segregation occurred and that the inheritance of sprouting resistance is not governed by a single gene. However the large proportion of resistant lines does not necessarily warrant genetical explanation. It is reasonable to consider that the rigid selection which was practiced each year on the basis of seed colour, plumpness and general appearance, eliminated more lines susceptible to sprouting than resistant lines. Such an explanation assumes a correlation between ordinary weathering, *viz.*, slight bleaching, and propensity to sprout.

The results indicate that lines of high sprouting resistance may be expected from crosses having at least one resistant parent and that even a cross between susceptible parents may result in some lines more resistant than the parents: for example, Quality × Ceres.

It is significant that while selection for good seed appearance may have increased the proportion of resistant lines retained it did not eliminate the lines with medium to low sprouting resistance. In fact 8 of the lines tested proved to be highly susceptible to sprouting. Thus the need for sprouting tests is evident.

Since there is close agreement between the results of the sprouting tests and those of the dormancy studies either type of test may be used as a practical method of determining the sprouting resistance. But owing to the uncertainty of the occurrence of suitable weather for field sprouting the use of laboratory dormancy tests would seem to be the better plan.

SUMMARY

1. Moist weather caused the germination of ripe wheat standing in the field nurseries at Saskatoon, Saskatchewan, in September, 1938, and a study was made of the comparative sprouting behaviour of 17 varieties and 157 purified hybrid lines from 4 crosses.

2. There was a wide range in the percentage sprouting of the standard varieties, the averages from 7 tests being as follows: Apex Sask. 1789, 3.9% (7 tests), Thatcher 6.5% (7 tests), Renown 8.4% (2 tests); Marquis 11.0% (7 tests), Reward 34.0% (5 tests), Reliance 47.8% (3 tests), Ceres 57.9% (4 tests) and Garnet 78.8% (7 tests). It was interesting to note that 3 new stem rust resistant varieties topped the list.

3. Among the hybrid lines of some crosses the parental range for sprouting was exceeded by 1 or more lines showing lower percentages of sprouting than the better parent.

4. The results on sprouting from material which matured 3 and 6 weeks respectively before the rains, agreed well with the results recently obtained in dormancy studies on the same varieties.

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THE MICROFLORA OF THE RHIZOSPHERE IN RELATION TO RESISTANCE OF PLANTS TO SOIL-BORNE PATHOGENS[1]

A. G. Lochhead,[2] M. I. Timonin[3], and P. M. West[3]

Science Service, Ottawa

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It has long been recognized that soil in the vicinity of the roots of growing plants supports usually noticeably higher numbers of micro-organisms than soil more distant from the plants. Recent investigations (1, 3) have shown that not only are purely quantitative differences manifest between rhizosphere and control soil, but the qualitative nature of the soil microflora is markedly influenced by the growing plants, with respect to both the morphology and physiology of the predominant bacteria. Effects of a similar nature have been noted with seedlings, and with more mature plants from the field.

In the course of investigations of the rhizosphere of various crop plants, studies were included to compare certain varieties of plants regarded by plant breeders as resistant and susceptible respectively to soil borne d sease in which definite pathogens are involved (Wilt of flax and black rootrot of tobacco). Observations made from investigations of the rhizosphere microflora by different methods of approach, *viz.*, quantitative, morphological and physiological, together with details regarding methods, will be included in separate presentations elsewhere (1, 2, 3). However, it was of interest to note that the various comparative studies gave results of similar trend, and provided an accumulation of evidence suggestive of inherent differences in the physiology of resistant and susceptible varieties of the same plant resulting, in the case of the susceptible varieties, in a more pronounced "rhizosphere effect."

QUANTITATIVE

Estimations of total numbers of micro-organisms by the plating method (2), summarized in Tables 1 and 2, indicated that the susceptible varieties of both flax and tobacco supported in their rhizosphere higher numbers of bacteria and fungi than did corresponding resistant varieties of the same crop plants. In the case of actinomycetes less significant difference was apparent.

Table 1 shows plate counts in a direct comparison between the varieties. Data are included from analyses of field samples of flax and tobacco and from seedling tests with tobacco. In the latter case 13 samples of seed, distinguished by number only, were received from the Tobacco Division, Experimental Farms Service, and the findings later tabulated according to the degree of resistance as established by the plant breeders.

[1] Contribution No. 67 (Journal Series) from the Division of Bacteriology and Dairy Research, Science Service, Dominion Department of Agriculture, Ottawa.

[2] Dominion Agricultural Bacteriologist.

[3] Agricultural Assistant.

TABLE 1.—NUMBERS OF MICRO-ORGANISMS IN RHIZOSPHERE OF RESISTANT AND SUSCEPTIBLE PLANT VARIETIES (PER GM. RHIZOSPHERE SOIL)

	Bacteria	Antinomycetes	Fungi
Flax (Field Crop)			
Bison (Resistant)	13,100,000	2,100,000	48,500
Novelty (Susceptible)	18,100,000	3,000,000	75,600
Tobacco (Field Crop)			
RH. 211 (Resistant)	269,600,000	31,900,000	239,500
Ch. 38 (Susceptible)	505,400,000	155,200,000	939,700
Tobacco (Seedlings)			
Resistant (6 samples, aver.)	95,500,000	3,030,000	87,900
Intermediate (5 samples, aver.)	108,100,000	2,980,000	93,100
Susceptible (2 samples, aver.)	174,900,000	2,600,000	90,400

In Table 2 are summarized results from a more extensive test with flax varieties, in which the moisture content of the soil was maintained at 2 levels and by 2 procedures, the constant weight method and the moisture tension method, using pressure cells. The results, expressed as ratios of the rhizosphere count to that from the control soil, show higher ratios of bacteria and fungi with the susceptible than with the resistant variety. It was of interest to note that under drier soil conditions the ratios of the rhizosphere population to that of the control soil were definitely higher than when the soil contained a higher percentage of moisture. With actinomycetes there is much less difference between rhizosphere and control, with no varietal difference apparent.

TABLE 2.—MICRO-ORGANISMS IN RHIZOSPHERE OF FLAX SEEDLINGS RESISTANT AND SUSCEPTIBLE RESPECTIVELY TO WILT (RATIOS—RHIZOSPHERE/CONTROL SOIL)

Variety	Bacteria		Actinomycetes		Fungi	
	30%*	60%	30%	60%	30%	60%
	Constant weight method					
Bison (Resistant)	4.81	2.49	1.4	1.3	2.35	1.39
Novelty (Susceptible)	26.13	9.71	1.8	1.2	6.84	2.29
	Moisture tension method					
Bison (Resistant)	10.90	5.21	1.5	1.5	2.90	1.34
Novelty (Susceptible)	12.01	6.90	1.5	1.4	4.60	2.02

* Percentage saturation of soil.

QUALITATIVE

Bacterial Morphology

In a comparison of the relative incidence of different groups of soil bacteria as affected by the growth of various crops it was found (1) that a selective action was apparent, characteristic of the rhizosphere of all plants studied, with respect to 4 morphological groups. The crops studied included clover, mangels, oats, flax, corn and tobacco. In all cases gram-negative short rods were proportionately increased, whereas gram-positive short rods, coccoid rods and spore-forming types were relatively less numerous in the rhizosphere than in soil more distant from the plant (Figure 1). No definite effect of the plant was noted on the relative abundance of the other 4 groups into which the organisms were divided.

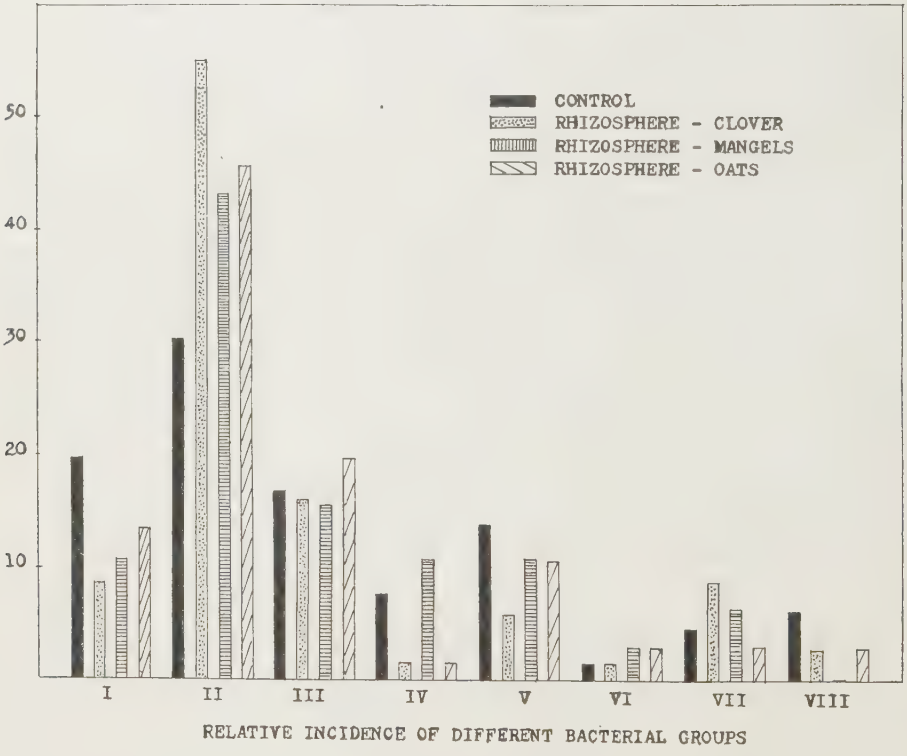

FIGURE 1. Relative incidence of bacterial groups in rhizosphere of clover, mangels and oats, and in control soil.

I. Gram positive short rods
II. Gram negative short rods
III. Gram variable short rods
IV. *Bact. globiforme*
V. Coccoid rods
VI. Cocci
VII. Long rods, non-sporing
VIII. Spore formers

The relative incidence of bacterial groups which reacted to plant growth was determined in the rhizosphere of resistant and susceptible flax and tobacco varieties. Results are presented graphically in Figure 2. and indicate that with both plant species studied, a similar trend is observed with all 4 groups of organisms. Whether the relative incidence increases or decreases in the rhizosphere of the resistant variety as compared with the control soil, the effect is more pronounced with the susceptible plants.

Physiological (Nutritive Requirements of Bacteria)

In an adaptation of similar quanti-qualitative methods to a comparison of certain physiological aspects of the rhizosphere micro-organisms, comparison was made of the relative incidence of bacterial groups according to their nutritive requirements (3). This was determined by noting growth responses in a series of media of increasing complexity, shown by bacteria isolated from control soils and from the rhizosphere of resistant and susceptible plants (flax seedlings, and tobacco grown under field conditions).

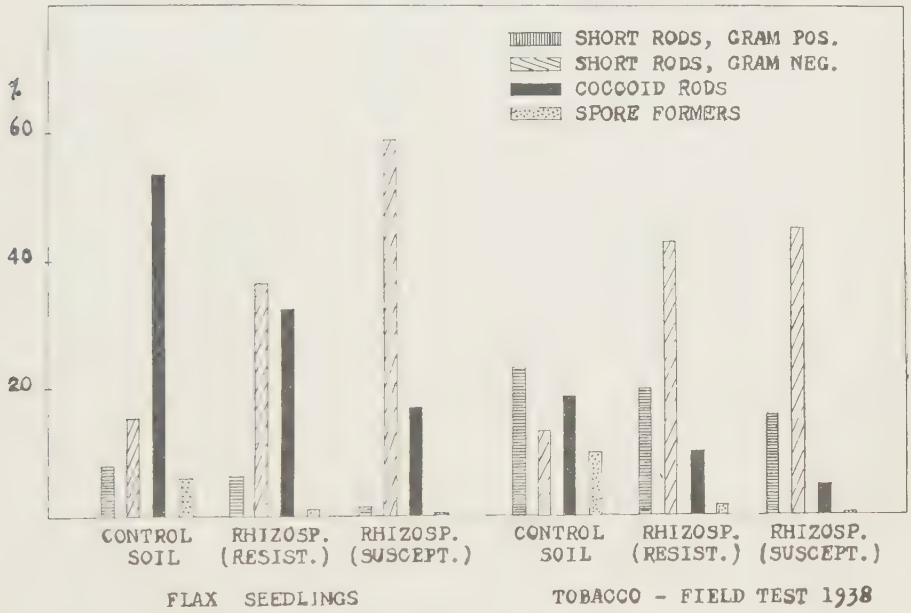

FIGURE 2. Relative incidence of morphological groups of bacteria in rhizosphere of resistant and susceptible plants, and in control soil.

The increased complexity of the growth requirements of the rhizosphere bacteria as compared with those from soil more distant from the plant is illustrated in Figure 3. However, differences between resistant and susceptible varieties were noted. Organisms from the rhizosphere of the resistant flax variety showed an 83% proportionate increase over the control in numbers for which amino-nitrogen was either stimulative or essential, while organisms from the susceptible variety showed an increase of 325%. In the case of organisms influenced by a combination of growth factors, of which thiamin and biotin were particularly significant, the respective percentage increases were 71 and 143. Similar trends were noted in the case of the tobacco varieties and suggest that similar fundamental factors

are operative as in the case of flax. The results thus support the findings from the quantitative and morphological studies in indicating a more pronounced "rhizosphere effect" in the case of the susceptible than in the case of the resistant varieties studied.

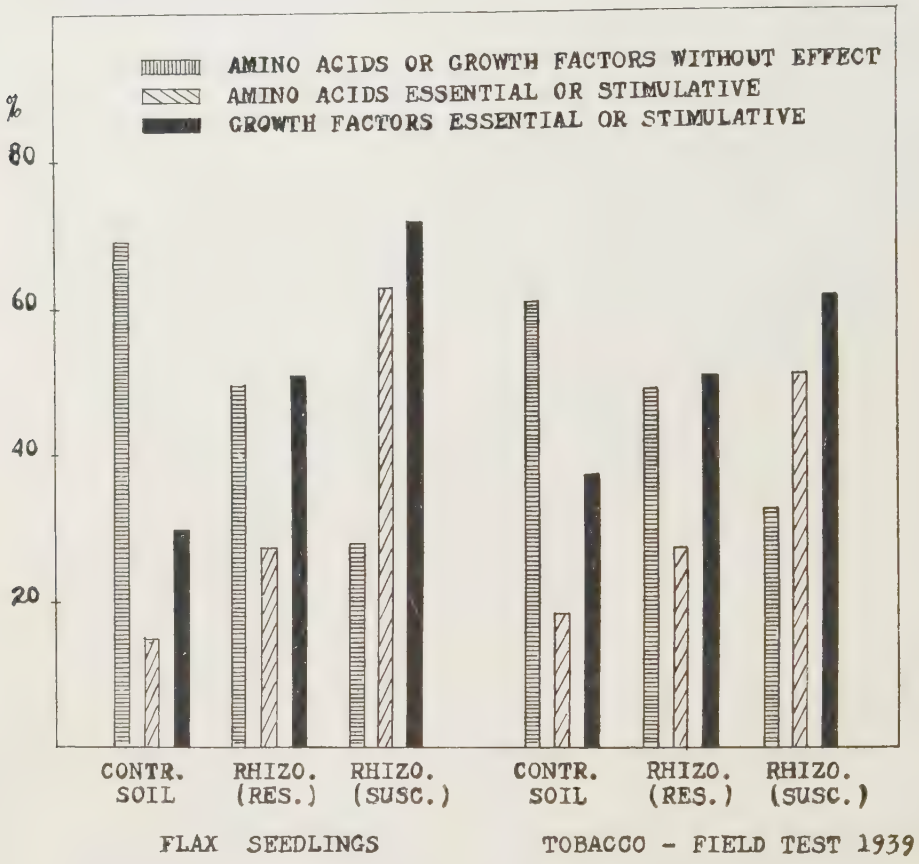

FIGURE 3. Relative incidence of bacteria of different nutritive requirements in rhizosphere of resistant and susceptible plants, and in control soil.

SUMMARY

Comparative studies were made of micro-organisms in the rhizosphere of varieties of flax resistant and susceptible respectively to wilt and of varieties of tobacco resistant and susceptible to black rootrot. Evidence which has accumulated from both quantitative and qualitative investigations indicate modifications in the rhizosphere suggesting inherent differences between the resistant and susceptible varieties studied, resulting in a more pronounced "rhizosphere effect" in the case of the susceptible plants.

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THE RATE AND MODE OF PENETRATION OF HERBICIDES

I. COPPER NITRATE SOLUTIONS[1]

W. H. Silversides[2]

The University of Manitoba, Winnipeg, Man.

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Copper nitrate solutions have been used successfully as a herbicide in the partial eradication of dandelion plants from lawns. While the action of the spray is one primarily of destruction of the foliage it was felt that more knowledge regarding the mode of destruction of the leaf tissue was needed.

REVIEW OF LITERATURE

While nothing definite has been published, to the author's knowledge, on the rate or mode of penetration of copper nitrate into leaves, there is a considerable volume of literature regarding the action of sulphuric acid and copper sulphate in penetrating leaf tissue. Crafts (4) found that sulphuric acid slowed down the streaming of the protoplasm, when *Elodea* leaves were used, causing it to swell, become viscous, and completely permeable. It was also found by this worker that the acid solution caused the chlorophyll to change from a green to a light yellowish green colour. The cuticle of leaves is fairly permeable to water vapour, and sulphuric acid was found to diffuse readily into morning glory leaves. The stomata were found to play little or no part in the penetration of acid sprays. Aslander (2) found humidity and temperature to play an important part in the effectiveness of sulphuric acid and iron sulphate when used as herbicides. He found that the protoplasmic streaming in the leaves of *Elodea canadensis* Rich. continued for 2 hours in a solution of 10% iron sulphate, but ceased in 30 seconds in a 1% solution of sulphuric acid. The cells were killed after having been kept in the iron sulphate solution for 3 hours or in the sulphuric acid solution for 2 minutes. Aslander (1) cites results gained by observations made using sulphuric acid as a herbicide as follows: (this summary is also given in reference Aslander (2).)

Sulphuric acid adhering to the surface of plants penetrated rapidly and killed the protoplasm almost instantly. In this reference Aslander states that the cells under the stomata seemed to be damaged first but also that the spray penetrated through the epidermal cells. It was found that sulphuric acid spray decomposes chlorophyll as it unites with the magnesium atom of the chlorophyll molecule. The acid was found to break down the chloroplasts. In cells penetrated by the acid the cell content formed a deeply stained mass in which no chloroplasts could be seen. The cell walls of the epidermis were found to be relatively uninjured, due likely to its cellulose composition which is not destroyed by dilute sulphuric acid, while the cells of the spongy parenchyma sometimes seemed to be destroyed, due to the fact that they are pectin (or pectin in combination with calcium)

[1] Contribution from the Division of Plant Science, University of Manitoba, with financial assistance from the National Research Council.

[2] Graduate Assistant (Weed Research).

compounds, and are dissolved by the action of dilute sulphuric acid. The destruction of the leaves after the spray was applied was so rapid and complete that the fate of the cell walls was difficult to determine.

Dandero (5) in an investigation into the effects of aqueous solutions of some inorganic substances on foliage leaves found that brown rings were formed when copper sulphate solutions were absorbed by *Ampelopsis*. He also found that dilute solutions probably stimulated tissues and concentrated solutions of copper sulphate caused scorching. Brenchley (3) states that as a rule copper compounds are poisonous to the higher plants except in great dilution where a stimulating action may be manifested. Little is known as to the physiological action of copper especially with regard to its entry into the plant and its mode of action within the plant cells.

PROCEDURE

Dandelion leaves were collected from plants that were sprayed with copper nitrate solutions. An infested area on the University of Manitoba campus was treated on August 17, 1938. A 2% copper nitrate solution was applied to the infested blue grass lawn at the rate of 200 gallons per acre. The weather at the time of treatment was hot and sunny. A knapsack sprayer was used which delivered a fine misty spray. The leaves were collected from sprayed plants at intervals after the spray was applied. After collection the leaves were dipped into water and then placed in vials of chrom-acetic formalin killing-fixing solution. Paraffin sections were made of the damaged leaves, and stained with safranin.

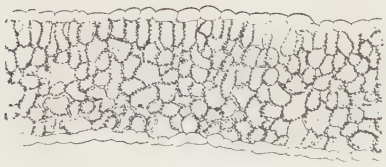
RESULTS

The effects of the spray on the dandelion leaves are best seen in the accompanying copies of photomicrographs of typical damaged leaves (Plate I). Data from observations, however, on the appearance of the treated dandelion leaves at the time of collection are presented in Table 1. Table 2 describes the appearance of the sections at the time they were examined under the microscope. The illustrations show the gradual infiltration of the spray into the dandelion leaves.

It was found that the epidermal cells were generally less damaged than the cells of the parenchyma. It was also noted that in the treated areas of the leaf the chloroplasts could not be distinguished and there was a tendency for the damaged tissue to take on heavy staining. This fact was also noted by Aslander (2). An examination of the sections also shows that the damage to the parenchyma does not seem to appear first under the stomata. It appears that the spray penetrates the epidermis chiefly.

Complete penetration by the copper nitrate spray into the leaf was first noticed in leaves that had been collected 30 minutes after treatment.

PLATE I. 1. Section of Dandelion leaf before treatment. 2. Section of Dandelion leaf, 10 minutes after treatment with copper nitrate spray. 3. Section of Dandelion leaf, 20 minutes after treatment with copper nitrate spray. 4. Section of Dandelion leaf, 30 minutes after treatment with copper nitrate spray. 5. Section of Dandelion leaf, 50 minutes after treatment with copper nitrate spray. 6. Section of Dandelion leaf, 60 minutes after treatment with copper nitrate spray. 7. Section of Dandelion leaf, 70 minutes after treatment with copper nitrate spray. 8. Section of Dandelion leaf, 1 hour 40 minutes after treatment with copper nitrate spray. 9. Section of Dandelion leaf, 3 hours after treatment with copper nitrate spray. 10. Section of Dandelion leaf, 18 hours after treatment with copper nitrate spray.



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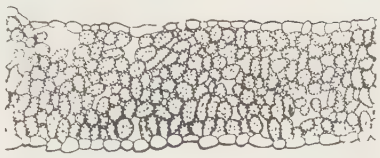

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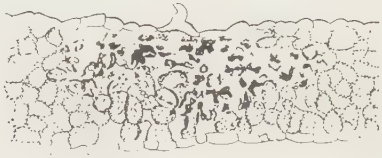

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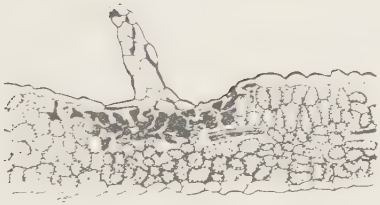

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PLATE I.

TABLE 1.—OBSERVATIONS ON THE APPEARANCE OF DANDELION LEAVES AT INTERVALS AFTER SPRAYING WITH A 2% COPPER NITRATE SOLUTION

Time after treatment	Damage	Remarks
10 minutes	None	Dandelion leaves wet with spray.
20 minutes	None	Dandelion leaves dry; no apparent damage.
30 minutes	None	Dandelion leaves dry; no apparent damage.
40 minutes	Brown spots	Dandelion leaves becoming flaccid.
50 minutes	Brown spots	Leaves beginning to curl at the edges and becoming flaccid.
1 hour	Brown spots	Leaves curled and flaccid.
1 hour, 10 minutes	Leaf wilted	Leaves curled, brownish spots prominent.
1 hour, 40 minutes	Leaf wilted	Leaves curled, brown spots prominent on treated surface.
2 hours	Leaf wilted	Leaf curled and wilted, brown spots very prominent.
3 hours	Leaf crisp	Leaf curled and becoming dry.
18 hours	Leaf shrivelled	Leaf brown in colour, dry at the leaf margins and crisp to touch.
24 hours	Leaf collapsed	Leaf totally brown and shrivelled.

TABLE 2.—OBSERVATIONS ON SECTIONS OF DANDELION LEAVES TAKEN AT INTERVALS AFTER SPRAYING WITH A 2% COPPER NITRATE SOLUTION

Time after treatment	Remarks
10 minutes	No obvious killed or damaged cells in the treated leaf.
20 minutes	Some obvious damage. In some cases the spray had penetrated as far as half way through the leaf. The epidermis was not apparently damaged.
30 minutes	Obvious damage observed. Penetration of the spray was found as far as two-thirds of the way through the leaf. The epidermis of the leaf did not appear damaged.
40 minutes	The penetration of the spray was from two-thirds to complete in some cases. Where only a very small particle of the spray was deposited, the rate of penetration seemed to be much slower. Some of the epidermal cells in the specimens examined were damaged.
50 minutes	All stages of penetration of the spray from one-third to complete were found.
1 hour	Partial to complete penetration of the leaf by the spray was found.
1 hour, 10 minutes	Partial to complete penetration of the leaf by the spray was found. Both the upper and lower epidermal cells were damaged. In the specimens examined there was a complete collapse of the cells under the areas where the spray fell. It was noted that the leaves in some specimens had become wrinkled where the copper nitrate had been active.
1 hour, 40 minutes	The penetration of the spray in most cases was complete. The damaged tissue had caused some shrivelling of the leaf.
2 hours (no figure)	Partial to complete penetration of the spray. A complete collapse of the epidermal cells was noted in cases where penetration of the leaf was complete.
3 hours	Penetration of the spray for the most part complete. The epidermal cells in some cases did not seem to be damaged, as much as the palisade cells.
18 hours	Where penetration is complete the upper and lower epidermis have been drawn together, making a constriction in the section.
24 hours (no figure)	Complete penetration in nearly all examined specimens. The cell walls in most cases have collapsed, but in some the epidermal cell walls are partially intact.

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THE PHYSIOGRAPHY OF EASTERN ONTARIO

L. J. Chapman and D. F. Putnam

Ontario Research Foundation, Toronto, Ont.

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The area indicated by the title is that part of the Province lying east of the meridian of Kingston and including, also, the upper Ottawa valley as far up-stream as Chalk River. Lying between the St. Lawrence and Ottawa Rivers, it is roughly triangular in shape and about 6,000 square miles (4,000,000 acres) in extent. There is, in divers geological reports, much information about the bedrock and overlying drift of this area, but complete information about those qualities that influence soil character is usually wanting. Having recently made a survey of the region to chart the surficial geological features and to obtain outstanding knowledge of those materials which constitute the parent materials of the soils, we submit the following account of the physiography of Eastern Ontario.

THE BEDROCK

Broadly speaking, these eastern counties form part of the St. Lawrence lowlands between the Laurentian highlands of Quebec, Ontario and New York, and the mountains of Vermont and Eastern Quebec. The bedrock originated as sediments in Palaeozoic seas and consists of sandstones, dolomites, limestones and shales. The distribution of these rocks, according to the Geological Survey of Canada, is shown in Figure 3. The Potsdam sandstone rests directly on the knobby Pre-Cambrian rocks above which are the younger strata; the Beekmantown dolomite, Chazy shale, Chazy limestone, Black River limestone, Trenton Limestone, Utica shale, Lorraine shale and Medina shale resting conformably upon each other in that order. Their stratigraphic arrangement is shown in Figure 4, which depicts a cross-section extending from a point near Carleton Place on the west to the Ottawa River near Hawkesbury. The topography of the upper rocks is fairly level, but small ledges or cuestas are frequent on the Beekmantown dolomites in the western part and in several places there are fault scarps; for example, one extends from the vicinity of Ottawa towards the village of Russell. The rocks to the north of this scarp are down-faulted so as to bring the Lorraine shale below the Beekmantown dolomite, proving a displacement of 1,500 feet or more. The scarp itself is mostly less than 50 feet in height.

From the standpoint of their influence on the composition of the till, the occurrence of the red Medina and the grey shales in Prescott, Russell and the north-western part of Carleton county is significant. These soft rocks gave rise to a shaly, glacial till which is distinctly different from that found in areas underlain by limestone. The Trenton limestone, common to most of Glengarry and Stormont counties, is also easily broken up and, therefore, is generally covered with a good depth of till. The dolomite in the western section is a harder rock which yielded less readily to the glaciers and gave rise to an area of very shallow drift similar to that found

on the massive Black River limestone in Lennox and Addington and Frontenac counties. Wherever it outcrops, the Potsdam sandstone readily yielded material which now appears in the till. Finally, the important influence of the granite, quartzite, gneiss, crystalline limestone, etc., of the Laurentian highlands in Quebec should be mentioned. Since the glacier

FIGURE 1. A key map of Eastern Ontario.

advanced from that direction it collected and transported a considerable amount of these materials to mix with the local rocks in the till of Eastern Ontario. The frequent occurrences of apatite deposits in Quebec is also notable on account of its possible influence on the phosphorus content of the soils.

OUTLINE OF PLEISTOCENE AND RECENT GEOLOGY

It is well known that this section of the continent was subjected to at least three glaciations, but nowhere in Eastern Ontario has there been found evidence of more than two invasions. For example, at Lot 17, Con. IX of Finch township, there is an exposure made by the Payne River showing a section from the bedrock to the surface. Directly over the rock are several feet of glacial till overlain by stratified clay, silt and sand, undoubtedly interglacial, above which is another bed of boulder clay capped by the marine clays of the district. While previous glaciations are not without interest, nevertheless the surface deposits and, therefore, the last (Wisconsin) glaciation is our main concern.

The first land to be uncovered by the melting glacier was that in the extreme south-west near Kingston. However, it must be borne in mind that Lake Iroquois was then in existence and its waters washed the edge of the receding glacier (8). It should also be borne in mind that this section of the continent was then several hundred feet lower, relative to the sea, than it is now. In fact, it was well below sea level so that the down-draining of Lake Iroquois, due to the retreat of the ice from Covey Hill in northern Vermont, was immediately followed by the inception of Gilbert Gulf. Gilbert Gulf is the name given to the arm of the sea which entered this area following the recession of the glacier. The direction of ice movement in the Kingston vicinity was roughly parallel to the St. Lawrence, while farther east the direction was a little more nearly north and south. South of Ottawa the drumlins point in a north and south direction, and further up the Ottawa valley the striae run in a southeasterly direction, showing that the movement here was directed by this topographic feature. From the foregoing it is deduced that, in this area, the retreating ice-front extended in an approximately east and west direction, the upper Ottawa valley being uncovered last.

FIGURE 2. A sketch map showing the relief of Eastern Ontario.

At the time of maximum invasion the sea extended up the Ottawa valley as far as Lake Temiskaming and covered the main body of the region to a depth of 200 or 300 feet. It was over 400 feet deep at Ottawa.

On being relieved of its burden of ice the territory commenced a series of uplifts which eventually raised the land above sea level. The upper Ottawa valley, having higher altitude, was the first to rise above the sea, and the last to become dry land was the low area near the Ottawa River east of the city of Ottawa, and lands of similar altitude near the St. Lawrence in Glengarry and Stormont counties. The recession of the sea from the region occasioned the beginning of the rivers which then began the work of entrenching themselves into their present channels.

The accumulation of peat in the numerous bogs has been going on since the marine epoch and, of course, is still proceeding.

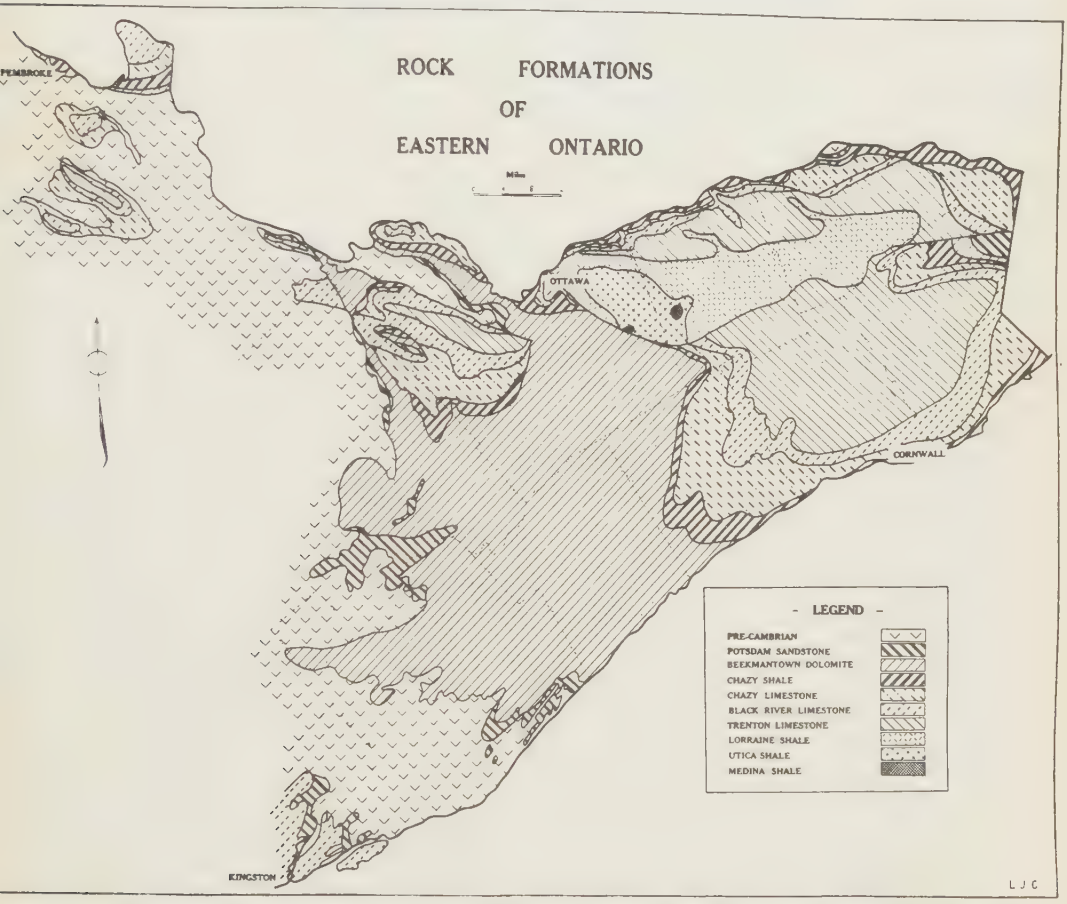

FIGURE 3. Bedrock map of Eastern Ontario. (From maps of the Geological Survey of Canada).

GLACIAL DEPOSITS

Ground Moraine

First of all, the till found on the irregular Pre-Cambrian rocks, which occupy much of Leeds county, outcrop in Carleton and Renfrew counties and border the entire region on the west, should be mentioned. There is, generally, only a shallow depth of till on these rocks, or none at all. Especially in those areas which were covered by the sea and subjected to the

action of the waves are the rock-knobs apt to be bare, the till having been washed off. This condition is usually found throughout the area covered by this survey, but near Westport in Leeds county, between White Lake and Burnstown and at various places in Renfrew county there is deeper till consisting largely of Pre-Cambrian materials. In that part of Leeds county occupied by the Pre-Cambrian the hollows between the rock-knobs are mostly covered with water-laid clays, burying the till.

Immediately east of the Pre-Cambrian boundary in Leeds, Grenville, Lanark and Carleton counties there is a large tract of very shallow till on the more level Beekmantown dolomite. Smaller areas occur throughout the region on limestone. A few inches, generally, and a few feet of till in exceptional spots produce shallow, drouthy soils on the more elevated portions, while swamps occupy the depressions. Between Ottawa and Kemptville there is a notable exception: about Manotick and North Gower there is the best field of drumlins found in the region. The most apparent explanation of the formation of drumlins in that locality is in the extra material available to the glacier from the shales to the north. Also, the better-than-usual loading place for the glacier afforded by the norward-facing fault scarp between Ottawa and Russell may have brought about the yielding of more dolomite than usual. There are many drumlins in Dundas, also, but the southern part of the county has much till only a few feet in depth. This moderately shallow boulder clay prevails also in Stormont and Northern Glengarry. The greater part of Glengarry and the adjacent part of Stormont are favoured with deeper till consisting mostly of Trenton limestone. It is similar to the till of Peterborough county with the exception that it contains pieces of Potsdam sandstone. It is a rolling terrain of imperfectly formed drumlins, the deeper spots having at least 50 feet of till which grades down to a few feet, generally, in the hollows.

It is of interest to speculate about the lack of well-formed drumlins in the Glengarry section. In this respect it has a good counterpart in the Murray Hills in Northumberland county. There, the formation is clearly due to the movements of the glacial lobes convergent upon that point:

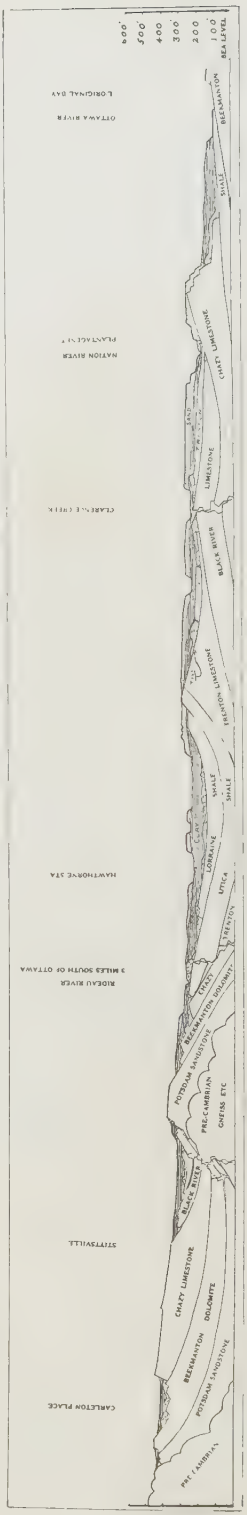

FIGURE 4. Diagrammatic cross-section showing bedrocks and overlying deposits.

to the north the movement was slightly west of south and to the east it was in a southwesterly direction. The opposing movements met along a line from the Murray Hills to Pancake Hill in Huntington township. There was a similar conflict of ice movements in Glengarry. Eastward,

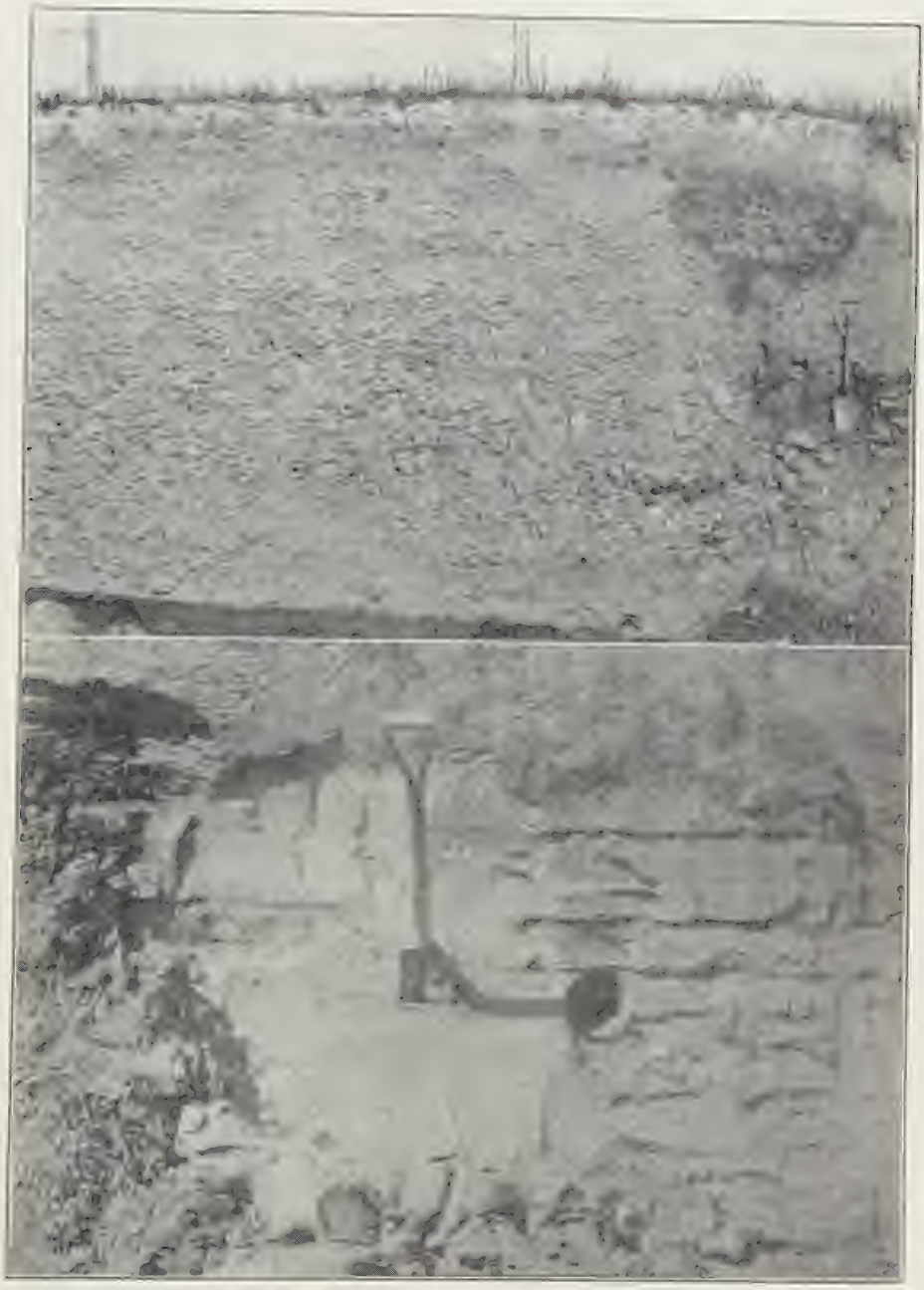

FIGURE 5. Typical marine clay of the sort common in Russell and Prescott counties. Note the massive, waxy character.

FIGURE 6. Marine beaches in Fitzroy township. *Left* parallel strands. *Right* limestone shingle.

the movement was roughly parallel to the St. Lawrence, while northward, it moved almost directly south. It is known that drumlins most readily form under a deploying ice lobe, and it is suggested that the lack of typical drumlins in Glengarry and on the Murray Hills is due to the opposite type of movement discussed above.

South-east of Ottawa, in Carleton and Russell counties, there are limited areas of ground moraine not covered by clay or sand. North of Russell village the till is reddish and consists largely of red Medina shale. In the surrounding district the grey shales similarly characterize the till wherever they appear. Appreciable amounts of shale from this source are present in the drumlins around Manotick and as far south as Kemptville. This mixed shale and dolomite till give rise to a very good soil.

Terminal Moraines

The only terminal moraine found in eastern Ontario is at Vankleek Hill. The short ridge upon which this village is situated has a rock core but the surface deposits are morainic. Like all moraines built in water, it presents a modest topographic form. The material is of limestone with the usual admixture of granite, quartzite, etc., and a little sandstone and shale.

Glacio-Fluvial Deposits

In addition to the boulder clays there are the sands or gravels laid down by the meltwaters at, or near, the edge of the melting glacier. Near Brewer Mills and Seeley Bay in Leeds county there are local sand hills which appear to be kames. Similar border-ice deposits occur near Algonquin on the Leeds-Grenville border, at Domville and other places in Grenville county, east of Lanark village and northwest of Manotick. The form of these sandy and gravelly deposits is smoother than customary due to the fact that they were dumped into standing water and later subjected to the planing action of the waves. In some places the characteristic, humpy, kame form is completely altered and the materials spread out to form a sandy plain. The extensive area of sand north of Cardinal along the Dundas-Grenville border is of this type. Smaller areas occur throughout Grenville county and among the drumlins in Dundas, Stormont and Carleton counties.

The eskers of the region have likewise undergone changes due to water action subsequent to their deposition; the knobby, serpentine form being much reduced and the extra sands spread out alongside. The best example of such an esker runs northward from a point about one mile east of Kemptville to Reids Mills and, intermittently, to West Osgoode and Leitrim, a distance of about twenty-five miles. Another runs northward from the village of Kars to a kame located one and a half miles north-west of Manotick.

MARINE SEDIMENTS

Marine Clays

During the marine invasion a great deal of clay, silt and sand were deposited. In 1863 a sketch map was published by the Canadian Geological survey under Sir William Logan (11) on which the clays were classified as Leda clays and Erie clays. The Leda clays were so named by Sir William Dawson after the presence of fossil shells of *Leda glacialis* (*Portlandia artica* Gray). However, what is more important from a soil standpoint is the depth and lime content of the clay.

As customary, these water-laid clays have a nearly level topography and so drainage is generally poor. Many of the peat bogs are underlain by clay. Only along the streams is there good natural drainage. The larger tracts are invariably of considerable depth. Well-drillers have reported 180 feet of clay at Wendover, 186 feet at Ramsayville and 220 feet at Breckenridge (9). There are deep beds in Dundas county but innumerable smaller patches of shallow clay occur throughout the adjacent sections of shallow drift.

FIGURE 7. Boulder beach. As seen near Greenfield.

It should be stressed at the outset that the various strata contain different amounts of lime carbonate; consequently it is not possible to determine how much lime was present, originally, in the surface layers in which the soil has developed. However, it may be said that the clays of Dundas and adjacent counties are the most calcareous, signifying the presence of limestone derived from local till; not all of the strata contain free carbonates, but one sample was found to have 13.5% of calcium carbonate (equivalents). The pink and grey clays may or may not contain carbonates; in only one of the five samples collected were they present and in this case the percentage (6.1) was not high. Finally, the grey clays of the upper Ottawa valley seldom show the presence of carbonates when tested with acid, which shows that they do not come from the grey limestone bedrock. Indeed, the low-lime character of all these clays indicates that the bulk of the material came from the Pre-Cambrian rocks of the surrounding uplands. North of Russell village the pink clays undoubtedly owe their redness to their content of Medina shale.

The Renfrew clays and those of the Carp valley are somewhat more silty than the others, and the pink clay is the most impalpable. Some idea of the physical nature of this latter type of clay may be obtained from Figure 5.

Delta Sands

At its maximum the sea extended up the Ottawa valley as far as Lake Temiskaming. It is pertinent to state here that the Mattawa River carried, during some of the time at least, the drainage waters of the Nipissing Great Lakes and was at least the equivalent of the present St. Clair River; while into Lake Temiskaming came the meltwater from a several-hundred-mile front of the waning glacier (3). It is to be expected that these large rivers would build a delta in the upper reaches of the estuary, and such sands are those occurring continuously from Pembroke northward. At the Petawawa military camp, for instance, the sand beds are about 100 feet in thickness.

FIGURE 8. River terrace and bluff near Hawthorne Station.

Further down-stream there are no deltas connected with the Bonnechere, Madawaska, Mississippi or Rideau rivers. This is remarkable in view of the extensive sand beds in the valleys of the hinterland through which these streams flow. However, the lack of deltas may be due to the fact that the streams pass through a chain of small lakes which acted as catch-basins for the sand. We hasten to add that this lack of deltas is a fortunate circumstance, since the sands would only have buried the marine clays which now constitute good agricultural land.

Beach Formations

At its deepest the sea covered the body of Eastern Ontario to a depth of 200 to 400 feet. At that time the waters would not likely have had much of a planing effect on the drift, except through the deposition of clay in the depressions. However, with the uplift of the region and the recession of the salt water, by stages, from the area there was a chance for the waves

to do their work. As a result there are throughout the region shore features at almost every vulnerable location. In the western section, almost every prominence of the Beekmantown dolomite is littered with shingle beaches or bars. The material was gathered and thrown up into ridges of varying strength which often appear as parallel strands in stepped fashion on slopes (see Figure 6). Kames and eskers underwent planing by the waves during this period and the majority of the drumlins were capped by a boulder beach or boulder pavement formed by the removal of the finer separates and the accumulation of the boulders from the till. This is the cause of so much excessively stony land that in due course served to test the physical strength and persistence of purpose of the early Scotch settlers. Nor is a good deal of it yet cleared of stones (see Figure 7).

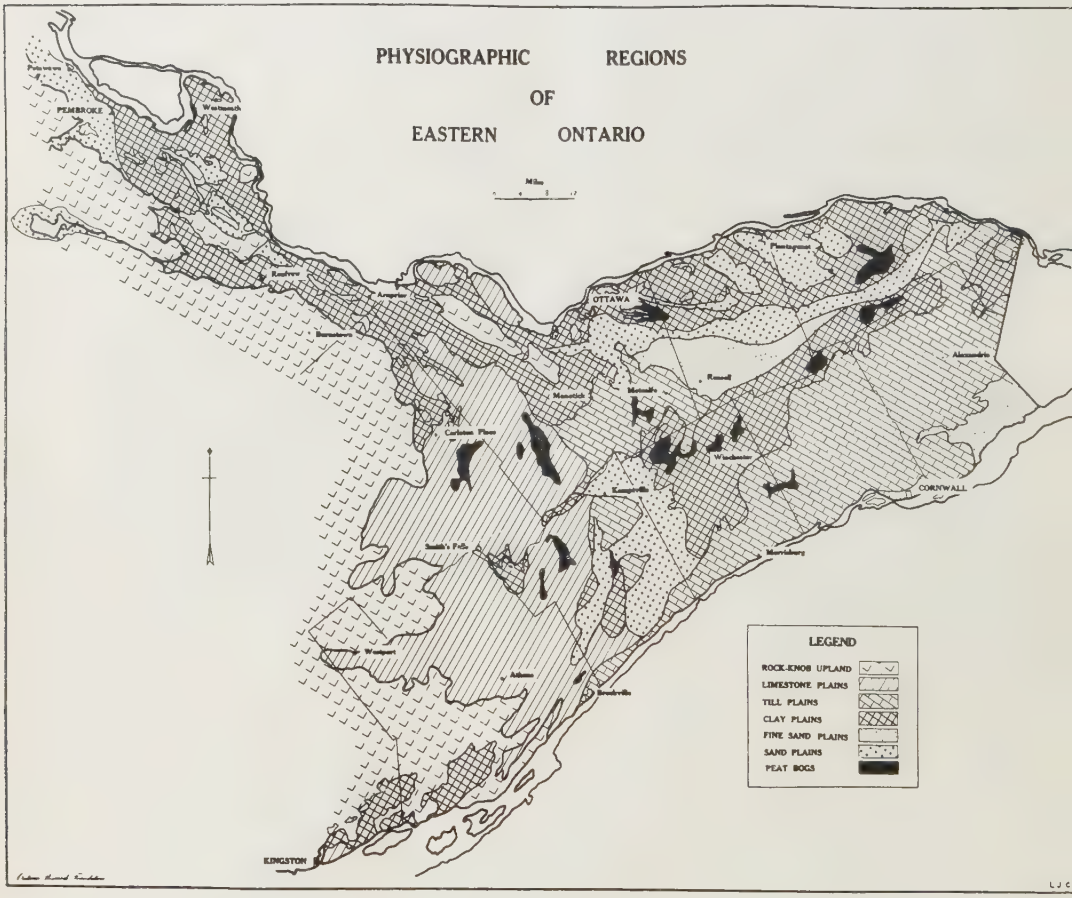

FIGURE 9. A generalized map of the Physiographic Divisions.

THE HISTORY OF THE OTTAWA RIVER

So far, the extensive sands of Carleton, Russell and Prescott counties have not been discussed. These beds have level topography and consist of horizontally stratified silt, fine and coarser sand. They rest on clay and are, apparently, typical delta deposits. They are low in lime, free

carbonates are usually lacking, and they appear to have come from Pre-Cambrian rocks. The question of the deposition of these sediments is taken up here because it is intimately associated with the Ottawa River or its larger forerunner.

FIGURE 10. Two landscapes on the till plains. *Top*—Rolling topography of the drumlinized upland, in Glengarry near St. Raphael W. *Bottom*—Shallow till in Stormont County near Northfield.

Following the stadial recession of the sea from the Ottawa valley the river commenced the task of entrenching itself in its present channel. By the time the uplifts had amounted to 415 feet in the Ottawa vicinity the sea had dwindled leaving only an arm extending up the lowlands adjacent to the Ottawa River in Prescott, Russell and Carleton counties, with its western extremity near where the city of Ottawa now stands. This latter point necessarily coincided with the mouth of the Ottawa River. In

keeping with this hypothesis there is the extensive delta in Carleton, Russell and Prescott, the westward extremity of which leads into a broad stream channel. This terrace, edged by stream-cut bluffs, runs continuously up-stream for at least 100 miles, since it appears to be contemporaneous with the 75-foot bluff which cuts across the military camp grounds at Petawawa. It is charted on Figure 2. The extensive silts and sands of Carleton, Russell and Prescott were transported from beds farther up the Ottawa valley and redeposited in this location. Subsequently, further uplift raised the newly-deposited delta above seal level and the Ottawa then proceeded to carve channels through these beds as shown in Figure 2. East of Ottawa, in particular, these later channels form a conspicuous physiographic feature (note Figure 8). In places the surface beds of sand and underlying clay were removed to a depth of 50 feet, leaving bluffs of almost that height although they are usually lower, 20 to 30 feet being common. From an agricultural standpoint, the work of the Ottawa is an asset since it removed thousands of acres of sand to uncover the same extent of clay which, in spite of its limitations, forms better soil than the sand. From a physiographic point of view, these stream terraces and bluffs constitute by far the most notable features of the sort to be found in Southern Ontario.

PEAT

The accumulation of peat in the numerous bogs of the region began at the close of the marine epoch and has been going on ever since. With the exception of local stream deposits which are of little consequence, the peat is the most recent of the surface deposits.

Some of the bogs are underlain by a bed of marl, which denotes the erstwhile presence of a pond or lake on that site. The Mere Bleue bog near Ottawa and the Alfred bog occupy positions in the bed of the abandoned channel of the Ottawa.

PHYSIOGRAPHIC DIVISIONS

The divisions to be made in this instance are not those broad separations to which the term "physiographic" is commonly applied; the whole region constitutes only part of such a unit. It is a much finer division based on the topographic form, depth and character of the surface deposits and the kind and configuration of the bedrock where it outcrops. Accordingly, 7 classes have been recognized and delimited on Figure 9, namely:

1. Rock-knob uplands
2. Limestone plains
3. Till plains
4. Fine sand and silt plains
5. Sand plains
6. Clay plains
7. Peat bogs

In the following paragraphs the outstanding characteristics of these several classes will be given.

Rock-Knob Uplands

This physiographic type is so well known that it is only necessary to mention the typical granite knobs of Muskoka, The Thousand Islands, Haliburton, Algonquin Park or Quebec by way of general description. Of course, besides granite there are other igneous rocks and crystalline rocks in the Pre-Cambrian. In the region under discussion there is considerable crystalline limestone. As a class they are hard rocks, so the glacial drift is scanty and the land better suited to forestry than agriculture.

FIGURE 11. Deep sand bed, southwest of Bourget.

In the places of lower altitude which were inundated by the sea the rock-knobs are invariably bare, the till having been washed off, and the hollows between may be floored with clay. The higher areas which were never flooded usually have a shallow covering of drift. It is, typically, low in lime but along the western fringe of the Palaeozoics there was some glacial drag of limestone onto the edge of The Shield to form a more calcareous till. This is well exemplified in the area between Renfrew and Burnstown.

Limestone Plains

This type was described in a former article (13) since it is widespread in Frontenac, Lennox and Addington, Prince Edward and Victoria counties. It is a condition of very shallow drift over sedimentary limestone bedrock. The fact that the associated bedrock in the eastern counties is a sandy dolomite, rather than a limestone, makes very little difference. The drift is mostly a stony till of the underlying material but shallow marine clay is

fairly extensive and sandy material occasionally found. Conspicuous features, not found in Central Ontario, are the marine beaches or bars which appear as crooked ridges of gravel or "shingle" on prominences, or as parallel strands in stepped fashion on the slopes.

These beaches, together with patches of deeper drift give rise to better soil, but, it may be said, that agriculturally, these limestone plains are of little value, and unfortunately, there are about 1,300 square miles of them in eastern Ontario.

FIGURE 12. Clay plain north of Renfrew.

Till Plains

In this category are included all those areas where any appreciable depth of glacial till forms the surface deposit. There are nearly 1,200 square miles of it and, as shown in Figure 9, it is widespread in Eastern Ontario, particularly in Dundas, Stormont and Glengarry counties. Southeast of Ottawa there are the red and the grey shale tills, to the south of which are the mixed shale, limestone and dolomite tills. In Glengarry, Stormont and Dundas the till is largely of limestone with the inevitable admixture of material from Pre-Cambrian sources and some sandstone from around the base of the Rigaud Mountain. The only terminal moraine of the region, at Vankleek Hill, is included with the drumlins and the shallower, less rolling till plains. The depth of the till is important and a separation on this basis is necessary from the standpoint of soil formation, although it cannot be shown on a small-scale map. The chief limitation of the soil developed on the deeper till is excessive stoniness. The shallow tills, as well as being stony, are usually poorly drained but where drainage is free the soils are drouthy and so are inferior lands. Figure 10 shows two typical landscapes of this type.

Fine Sand and Silt Plains

The distribution of the fine sand and silt is not scattered so it may be shown rather accurately even on a small-scale map. The main belt extends from Carleton county across the southern part of Russell and Prescott, and another tract is found in Southern Glengarry. Together they constitute an area of approximately 225 square miles. They represent the outer reaches of deltas where the finer sands and silt settled and, invariably, they are underlain by clay. Adjacent to the course sands there is a deep bed of fine sand and silt above the clay, which diminishes in depth until the clay plain is reached. Level topography and sluggish drainage

conditions characterize these plains. In this connection, stories of pioneer life in Glengarry record the struggle of the early settlers in clearing off the trees amid the mire of these flats. In many ways these sediments are similar to the fine sands of the Algonquin lake bed in Simcoe county, but instead of being highly calcareous they are very low in lime, being chiefly of Pre-Cambrian materials.

Sand Plains

Included under this heading are all the coarser sands which appear on the surface. The most extensive areas only are shown on the map, but in addition there are many smaller patches, omitted for practical reasons, which may easily be recognized by anyone wishing to make the identification. The estimated area is 700 square miles.

The extensive sands of Prescott, Russell, Carleton and Renfrew are largely of Pre-Cambrian origin and contain little or no limestone, while those of Grenville and Dundas usually contain free lime carbonate. Where the beds are deep or near stream courses, the drainage is good, in fact, usually excessive. On the other hand, where there is clay at a few feet a condition results in which the water table is high. This difference in drainage conditions results in the development of markedly different soil profiles but both types are poor. Figure 11 illustrates the deep beds of sand common in Russell county.

Clay Plains

The most extensive type of surface deposit in Eastern Ontario is the marine clay. It covers at least 1,600 square miles which is about 1,000,000 acres, or one-quarter of the total area. The clays are of three types: (1) those common to Dundas and Stormont counties, which usually contain lime carbonate and similar though slightly siltier deposits of the Carp valley; (2) the impervious, waxy, pink and grey clays of Russell and Prescott; and (3) the grey Renfrew county clays and silty clays which seldom show the presence of limestone when tested with dilute acid. Those in the vicinity of Ottawa are transitional in character, as are those of Leeds county. It is thought that the bulk of the clays were brought into the sea from Pre-Cambrian sources although some material was derived from local till. As shown in Figure 12, the clay plains have level topography and those areas shown on the map generally have considerable depth, 100 feet being not uncommon. The shallow clay deposits are found as inclusions in the shallower till areas and on the limestone plains. Occasionally, sandy knolls appear in the clay areas.

Peat Bogs

Eastern Ontario has extensive peat deposits, only the largest of which are shown on the map. Many smaller bogs occur in the areas of shallow drift and till plains and among the rock-knobs. The peat consists mostly of sphagnum moss and includes other marsh plants and trees such as tamarack, black spruce and white birch. It is usually fairly raw or undecomposed, with a strongly acid reaction. Some of the bogs have been considerably studied as a source of fuel or peat moss (11, 5), but as far as we are aware it is at present only used for fuel by local farmers whose clay lands have been entirely cleared of woods. It is cultivated only to a limited extent; much shallow peat has been burned off in Dundas, Russell and Prescott counties in order that the underlying clay might be developed.

SUMMARY

Eastern Ontario comprises that part of the St. Lawrence lowland lying within the Province east of Kingston. It is largely underlain by sedimentary rocks of the Ordovician system which have departed but little from their original horizontal attitude, but it also includes the more low-lying border areas of the Laurentian Shield, some of which were undoubtedly covered, before glaciation, by sedimentary rock. Subsequent to glaciation it was drowned by the sea and so its surface in part is now covered by unconsolidated deposits, but there are large areas of very shallow drift and rock outcrop.

In some instances the same type of topography and surface deposit are present in continuous areas of several hundred square miles, while other sections are much less uniform and consist of a patchwork of several types. We have not attempted to name and describe individually each of the smaller units but they have been classified and mapped under seven categories, the chief characteristics of which have been summarized in Table 1.

As was the case in Central Ontario (13), the present study was undertaken to provide a basis for the classification of surface geological materials in the course of a reconnaissance soil survey. It has been shown in South-Central Ontario (1) and in South-Western Ontario as well (12) that a strong correlation exists between the geological materials and the chemical properties of the soils developed from them. This is in accordance with the well known pedological principle that young soils exhibit more of the characteristics of the parent materials than do more mature soils in which the zonal or climatically determined features are predominant.

The study of the drift is then of even more importance in Eastern Ontario since the geological record shows that the actual time available for soil development is several thousand years shorter than in Western Ontario, where soil formation must have been fairly well established while much of Eastern Ontario was still beneath the sea.

TABLE 1

Region	Area in sq. m.	Altitude in feet above sea level	Topography	Character of deposit	Land use
Till plains	1200	200–400	Gently rolling	Loamy, limestone and shale tills, often very stony.	Deep till — Good general farming. Shallow till — Poor to fair farming.
Limestone plains	1300	350–500	Level or gently sloping.	A few inches of drift over stratified dolomite.	Poor pasture or waste land.
Clay plains	1600	200–450	Level	Deep marine clays.	Fair to good general farming.
Fine sand and silt plains	235	175–275	Level	Stratified, fine sand and silt over clay.	Fair general farming.
Sand plains	700	250–600	Usually level	Beds of sand over sand or clay.	Poor farming. Some reforestation.
Peat bogs	Over 125	200–300	Level	Bog.	Usually uncleared.
Rock-knob upland	750	400–1000	Knobby	Shallow drift, if any, over Pre-Cambrian rocks.	Forestry. Poor farming.

ACKNOWLEDGMENTS

We wish to mention here the suggestions, encouragement and support given us by Dr. H. B. Speakman and Mr. T. D. Jarvis of the Ontario Research Foundation. We are also indebted to Dr. Griffith Taylor of the Department of Geography, University of Toronto, for critically reading the manuscript.

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BOOK REVIEWS.

Imperial Bureau of Plant Breeding and Genetics School of Agriculture, Cambridge, England.

1. Bibliography on Cold Resistance.

Recent requests for information on the subject of cold resistance in connection with breeding for winter-hardiness have revealed the presence in our catalogue of a large number of bibliographical references to the subject, many of which, being of a general character, have not appeared in "Plant Breeding Abstracts." They are being published in the form of a bibliography which will deal not only with breeding for cold resistance and its technique, but also with physiological and other aspects of the problem. The number of references included exceeds 360 and they will be classified according to subjects and to crops, with adequate cross-references; indications will be given for finding the abstract of a paper where such has been published in "Plant Breeding Abstracts"; and there will also be an alphabetical author index.

The price of the bibliography will be 1/6 and applications should be made direct to the Bureau accompanied by remittance.

2. Field Trials: Their Lay-out and Statistical Analysis.

Every agricultural experimenter, not least the plant breeder, is called upon sooner or later to carry out field trials, whether it be to determine the effect of different treatments upon one and the same variety, or to determine the relative value of a number of varieties grown under identical conditions; or it may be even the two together, to determine the reaction of a number of different varieties to different sets of cultural conditions. The concern of the investigator at the present day is to find the most efficient way of arranging such trials and the correct way of working out and interpreting the resulting data, and there is a great need still for some straight-forward but authoritative exposition of these methods. The present bulletin fulfils just such a need. Written by the Reader in Statistics in the University of Cambridge, it is based on long experience of the difficulties of the layman in grasping the principles of applied statistics, experience acquired both in teaching students and in assisting research workers in the laying out and interpretation of experiments. The bulletin, though designed primarily for the use of plant breeders, will be equally invaluable to experimenters in all branches of agricultural science. It is throughout couched in as nearly as possible non-technical language and all technical terms used are defined. It begins with a clear exposition of the nature of the problems confronting the field experimenter; there follow sections devoted to the methods of randomized blocks and the Latin Square, multiple factor experiments, confounding and experiments with large numbers of varieties. All the methods are illustrated by examples.

The bulletin can be regarded as taking the place of the well-known Bulletin No. 10, "The Arrangement of Field Experiments and the Statistical Reduction of the Results," and serves as an introduction to the more complex problems dealt with in Bulletin No. 35, "The Design and Analysis of Factorial Experiments," both published by the Imperial Bureau of Soil Science.

Attention may be called to the very moderate price of the bulletin, which has been fixed at 2s. 6d. (two shillings and sixpence). Applications made direct to the Bureau should be accompanied by a remittance.

ERRATA

Volume XX, No. 6. "Dormancy in wheat and barley varieties in relation to breeding."

P. 363. The last three paragraphs commencing with, "The paper listed as . . . . ." do not belong to this paper but were inadvertently transposed from the bottom of P. 364.

Volume XX, No. 1. "The relation between changes in the rural population and the trend of agricultural production in British Columbia." P. 89—

Line 10. "Moreover, in 1921 no figures are available for occupational distribution except for a few cities." Read "Moreover, in 1921 no figures were available . . . . .". Volume IV of the 1921 Census in which there are, of course, data covering occupational distribution was not at hand. In any case the 1921 figures were in no case used as a basis for the estimate. It was stated below that we were only concerned with an estimate of the rural population for 1937 and that for this purpose the Census data for 1931 and the School Population data for subsequent years were adequate for our purpose.

Line 20. "In the census of 1931 the total of all persons actively engaged in agriculture in British Columbia is given as 42,209 persons." In the above statement "43,638 persons" should be substituted for "42,209 persons."

Line 21. "Even if we add some 15,943 persons employed . . . .". This should read "Even if we add 8,935 persons . . . .". The figure 8,935 arises from a change in the tabulation of the Footnote as under:

"*Vegetable Products*		
Biscuits and Confectionery	490	
Bread and other Bakery Products	1,582	
Flour and Grain Milling	312	
Fruit and Vegetable Canning	468	
Vegetable Food Products n.e.s.	125	
Liquors, Beverages (not aerated waters)	507	
Tobacco, Cigars and Cigarettes	89	
	———	3,573

Animal Products		
Butter, Cheese and Condensed Milk	303	
Slaughtering and Meat Packing	696	
Other Animal Food Products, n.e.s.	27	
Fur Dressing, Fur and Hair	57	
Leather and Leather Products	312	
		1,395
Retailing		
Dairy Products	915	
Flour and Feed	263	
Fruits and Vegetables	785	
Meat, Poultry and Fish	1,986	
Wholesale Dealing		
Butchers and Slaughterers	18	
		3,967
Total		8,935

The above corrected information is taken from Vol. VII, pp. 730–734, 1931 Census.

The above changes in the illustrative data on p. 89 necessitate the following substitutions: 52,573 for 58,152; 119,190 for 131,834; 2.51 for 2.27; 20,256 for 36,144.

Observe that the change of the ratio from 2.27 to 2.51 strengthens the argument stated (p. 89) as follows:

"Are we to assume that the rural population is 2.27 (now 2.51) times greater than the agricultural population . . . . . There is something wrong with one or both of these figures."

It must be stated that the correction of data on p. 89 does not invalidate the basis of the subsequent estimate as these figures (p. 89) were used for illustrative purposes only and since they were considered unreliable as a basis for a sound estimate of B.C.'s rural population, they were discarded (as stated in the text) and a new basis of estimation was substituted. The main difficulty in arriving at a basis for an estimate of rural population in B.C. was and still is the census divisions of areas for rural population. In many cases, as stated in the text, these areas, designated as rural or agricultural, have in reality no rural or agricultural population to speak of. This necessitated adjusting the census data to meet my own definition which I think is much closer to reality and correlating by school districts as far as possible the school population on the "*corrected*" basis.

G. F. DRUMMOND.